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TURBINE ENGINE CONTROL SYNTHESIS. VOLUME II. SIMULATION AND CONTROLLER SOFTWARE

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Honeywell, Incorporated

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This technical report has been reviewed and is approved for publication.

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The objective was to determine whether optimal control synthesis methods provide superior means for designing jet engine controllers. The methods design controllers with more capability and/or can be exploited to provide less expensive hardware. For newer kinds of engines the cost to design should be less than for presently used methods. Volume I summarizes optimal control design methodology. A paper design of a command and disturbance controller shows that good power lever command response can be achieved; the same controller is designed to be insensitive to inlet duct buzz.

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20. Abstract (Continued)

A command controller is synthesized and wind tunnel tested. This controller is a good approximation to time optimal with surge-stall, TT4, and flameout constraints. Small-amplitude control responses are precise. There is strong stability. Volume II contains three Appendices. Appendix A contains the details of engine math models. The software for the wind tunnel controller is presented in Appendix B. Appendix C contains a derivation of rate model following. Volume III presents results of frequency response tests of a J85-13 engine operating in the APL wind tunnel. The data are reduced and models identified.

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APPENDIX A
COMPONENT MODEL SOFTWARE

Software models of the J85 engine are presented in this appendix. Two computer programs are discussed:

- Linearization
- Nonlinear engine simulation

Fortran listings of the two programs are presented in Tables A-1* and A-2. Both programs were written for the SDS-9300 computer.

The linearization program, discussed in the first part of this appendix, was used to generate linear engine models for the synthesis of linear optimal controllers reported in Section IV of Volume I.

The nonlinear engine simulation package is discussed in the second half of this appendix. This computer program is basically a Fortran version of the J85 NASA component model of Reference A-1.

LINEARIZATION PROGRAM

The function of this program is to generate linear models of the J85 engine. A Fortran listing of the program is presented in Table A-2 and discussed in the following paragraphs.

* For the convenience of the reader, all figures and tables are provided at the end of each appendix.

The discussion is divided into four sections which correspond with the main parts of the program:

- Trim point calculation
- Engine dynamics
- Linearization
- Input data

Trim point calculations are discussed in the first subsection, labeled Trim Routine, where steady-state set points for the engine are computed. This section of the program calculates the fuel flow required to maintain the nominal operating condition specified by the input parameters. Trim values of engine responses are also calculated in this subsection.

Engine dynamics are discussed in the next subsection. A nonlinear dynamic model of the engine is contained in a subroutine called DYNAMIC. The model is a reduced order-version of the NASA component model of Reference A-1. All gas dynamics have been removed from the model so that it contains only two states, spool speed and engine case temperature.

The linearization procedure is presented in the third subsection of this appendix, under Linearization Routine. Engine dynamics are linearized about a steady-state trim point.

Input data are discussed in the last subsection. Two sets of data are required to run the program. One set defines the nominal operating conditions, i.e., steady-state spool speed, geometry control positions, compressor inlet pressure, and rotor torque load. The other set contains steady-state engine component data, i.e., compressor stage data and turbine map data.

Computations in the linearization program proceed in the following order. First, engine component data are read in. Then input parameters defining the nominal operating condition are read. Next a steady-state trim point corresponding to the input parameters is computed. Finally, a linear model of the engine is obtained by linearizing the nonlinear engine dynamics about the trim point.

Trim Routine

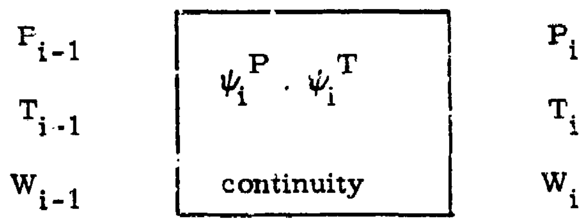
This section of the program generates steady-state trim solutions of the engine dynamic equations. Inputs to the routine include steady-state spool speed (N), geometry control position (IGV, BLD, A_8), compressor inlet pressure and temperature (P_o, T_o), exhaust nozzle discharge pressure (P_8), and external rotor torque load (SPLC). Given this set of inputs, the program iteratively computes a steady-state operating point. The computational procedure is summarized in the next paragraph.

First, steady-state values of the eight input parameters, N, A_8, IGV, BLD, P_o, T_o, P_8, and SPLC, are read in. Then initial guesses for fuel flow (WF), burner temperature (TB), turbine discharge pressure (PT), and inlet airflow (W_o) are made. Steady-state values of these four parameters are iteratively computed in four nested iteration loops. Steady-state values of all of the other engine variables are computed closed form.

Computations in the routine proceed in a manner analogous to the path followed by a particle of air entering the inlet; i.e., the compressor section is trimmed first, followed by the burner, the turbine, and finally the nozzle section.

The compressor is modeled by the stage stacking technique. Each stage is individually represented by a pair of experimental functions (ψ^P, ψ^T) which

are used to compute the pressure rise and temperature rise across the stage. Airflow through the stage is computed from the steady-state continuity relation.



ith stage

$$
\begin{aligned}
T_i &= T_{i-1} + f_1 \left[\psi_i^T , N \right] \\
P_i &= P_{i-1} \cdot f_2 \left[\psi_i^P , N, T_{i-1} \right] \qquad \text{(A-1)} \\
W_i &= W_{i-1}
\end{aligned}
$$

The stages are interconnected, or stacked, to form the compressor model where the discharge conditions of one stage are the inlet conditions of the following stage. Compressor bleed (BLD) and inlet guide vane (IGV) effects are included in the appropriate stages.

Thus, steady-state values of all the compressor variables can be computed closed form from a knowledge of the input parameters, N, IGV, BLD, P_o, T_o, and W_o. All of these inputs are specified, except for inlet airflow (W_o). This variable is computed iteratively in the outer iteration loop.

Burner performance is represented by three experimental relations, pressure drop across the burner (Δ PB), burner enthalpy (HB), and burner efficiency (η_B), together with the steady-state continuity relation. The pressure drop across the combustor is a function of compressor discharge pressure (PCD), burner inlet airflow (WB), compressor discharge temperature (TCD) and burner temperature (TB).

$$\Delta PB = f_1 [PCD, WB, TCD, TB] \tag{A-2}$$

Burner enthalpy is computed from a real gas experimental relationship which is a function of burner temperature (TB), burner airflow (WB) and fuel flow (WF).

$$HB = f_2 [TB, WB, WF] \tag{A-3}$$

Combustor efficiency is defined as the portion of the heat of combustion that is available for a gas temperature rise. It is computed from an experimental correlation of the form

$$\eta_B = f_3 [PB \cdot \Delta TB] \tag{A-4}$$

where

$$PB = PCD + \Delta PB$$

$$\Delta TB = TB - TCD$$

These three functions, f_1, f_2, and f_3, are functions of the three burner variables, WB, TB, and WF. One of these parameters, WB, is computed closed form (from the continuity relation), as

$$WB = WCD - WTC \tag{A-5}$$

where WTC is airflow which is bled from the compressor to cool the turbine.

The other two parameters, TB and WF, are computed iteratively in the inner two iteration loops.

The turbine is modeled by two performance maps, together with the steady-state continuity relation. Turbine enthalpy drop (ΔHT) and turbine airflow (WT) are represented as functions of burner temperature (TB), burner pressure (PB), spool speed (N), and turbine pressure ratio (PR_T).

$$HT = f_1 [N,\ TB,\ PR_T]$$

$$WT = f_2 [N,\ TB,\ PB,\ PR_T] \qquad \text{(A-6)}$$

These functions cannot be evaluated until the variable PR_T is computed. Although WT is established by the continuity relation

$$WT = WB + WF \qquad \text{(A-7)}$$

PR_T cannot be obtained closed form because the second function, f_2, cannot be inverted to solve for PR_T. Thus, PR_T is calculated in the third iteration loop.

The exhaust nozzle is represented as a variable area flow passage capable of choking. The mathematical relation is

$$\frac{WN \sqrt{TT}}{PT} = KNA8 \cdot A_8 \cdot f\left[\frac{P_8}{PT}\right] \qquad \text{(A-8)}$$

where

$$f\left[\frac{P_8}{PT}\right] = \left(\frac{P_8}{PT}\right)^{\frac{1}{\gamma}} \sqrt{1 - \frac{P_8}{PT}^{\frac{\gamma-1}{\gamma}}}$$

This expression is used to compute the nozzle airflow (WN).

Compressor inlet airflow (W_o) is systematically changed in the outer iteration loop until the nozzle airflow computed from the above relation agrees with nozzle airflow computed from the steady-state continuity relation

$$WN = WT + WTC \qquad \text{(A-9)}$$

Details of the trim routine are presented in the flowchart of Figure A-1.

First, the input variables N, A_8, IGV, BLD, P_o, T_o, P_8, and SPLC are read in. The last variable, SPLC, is a fictitious external torque load applied to the rotor shaft. If this variable is set to zero, the routine will identify a steady-state operating point on the engine equilibrium line. Nonzero values of SPLC cause the routine to identify quasi-steady-state operating points off of the equilibrium line. Quasi-steady state means that both N = constant and $\dot{N}$ = constant; the nonzero $\dot{N}$ is balanced by the external torque load SPLC.

Then, initial guesses of fuel-to-air-ratio in the burner (FAB), burner temperature (TB), and inlet airflow (W_o) are made. The parameter FAB is defined as

$$\text{FAB} \triangleq \text{WF/WB} \tag{A-10}$$

Thus, guessing a value of FAB is equivalent to guessing fuel flow.

Next, the integer variables which count the number of iterations are initialized to zero. The variables are defined as:

ITER1 -- number of iterations of the W_o loop

ITER2 -- number of iterations of the PT loop

ITER3 -- number of iterations of the TB loop

A counter is not assigned to the inner loop, the WF iteration. The variable III is a switch which is maintained as zero during the iteration process and set equal to one when all loops have converged.

In the next section of the program steady-state compressor variables are computed. Individual calculations are made for each compressor stage; the outlet conditions of one stage are inlet conditions of the next stage.

First, the pressure at the outlet of the inlet guide vanes is computed from the equation

$$P_{IGV} = P_o \cdot PR_{IGV} - 0.005\ P_o \tag{A-11}$$

where the IGV pressure ratio (PR_{IGV}) is calculated as a function of spool speed.

$$PR_{IGV} = PR_{IGV}[N]$$

Temperature and airflow, which are constant across the inlet guide vanes, are computed as

$$\begin{aligned} T_{IGV} &= T_o \\ W_{IGV} &= W_o \end{aligned} \tag{A-12}$$

The outlet conditions of the inlet guide vanes are the inlet conditions of the first compressor stage. Airflow in the first compressor stage is computed from the continuity equation

$$WC_1 = W_{IGV} \tag{A-13}$$

This airflow, together with T_{IGV} and P_{IGV}, are used to compute the axial component of velocity in the stage:

$$v_{z_1} = v\,[WC_1,\ T_{IGV},\ P_{IGV}] \tag{A-14}$$

which in turn is used to compute the flow coefficient

$$\phi_1 = K_{\phi 1} \cdot v_{z_1}/N \tag{A-15}$$

The constant $K_{\phi 1}$ in this expression is a function of the geometry of the stage. Next, pressure rise and temperature rise coefficients are determined from ϕ_1.

$$\psi_1{}^P = \psi_1{}^P [\phi_1, IGV]$$
$$\psi_1{}^T = \psi_1{}^T [\phi_1, IGV] \qquad \text{(A-16)}$$

Note the effect of inlet guide vane position is included in the first-stage coefficients. Finally, the pressure and temperature at the outlet of the stage are computed.

$$BC_1 = P_{IGV} \cdot \left(1 + \psi_1{}^P \cdot K_{\psi_1} \cdot N^2/T_{IGV}\right)^{\frac{\gamma}{\gamma-1}}$$
$$TC_1 = T_{IGV} + K_{\psi_1} \cdot N^2 \cdot \psi_1{}^T \qquad \text{(A-17)}$$

The constant K_{ψ_1} in these expressions is also a function of the geometry of the first stage.

Pressure, temperature, and airflow in the other compressor stages are computed in the same manner as the first-stage data. Calculations for the second and third stages are shown explicitly in the Figure A-1 flowchart.

Compressor bleed effects are included in the third, fourth, and fifth compressor stages. Bleed airflow in the third stage (WBL_3) is computed from the relation

$$WBL_3 = KBLD_3 \cdot BLD \cdot PC_3/ \quad TC_3 \qquad \text{(A-18)}$$

where

$KBLD_3$ is the bleed flow coefficient
BLD is the bleed area
PC_3 is the third-stage discharge pressure
TC_3 is the third-stage discharge temperature

The third-stage bleed airflow is subtracted from the third-stage inlet airflow (WC_3) to determine the inlet airflow to the fourth stage (WC_4)

$$WC_4 = WC_3 - WBL_3 \tag{A-19}$$

Bleed effects in the fourth and fifth stages are evaluated in the same way.

Compressor discharge relations are evaluated at the end of the compressor simulation section. The pressure, temperature, and airflow at the compressor discharge are the values at the outlet guide vanes.

$$\begin{aligned} PCD &= P_{OGV} \\ TCD &= T_{OGV} \\ WCD &= W_{OGV} \end{aligned} \tag{A-20}$$

Compressor discharge enthalpy (HCD) is evaluated as a function of TCD from a real gas model,

$$HCD = HCD\,[TCD] \tag{A-21}$$

Finally, the net change in airflow times enthalpy across the compressor is evaluated.

$$\begin{aligned} \Delta(WH)_{CD} = {} & WCD \cdot HCD + c_p(WBL_3 \cdot TC_3 + WBL_4 \cdot TC_4 + WBL_5 \cdot TC_5) \\ & - c_p \cdot W_o \cdot T_o + SPLC \end{aligned} \tag{A-22}$$

This change is proportional to the compressor torque load on the rotor shaft.

Next, steady-state airflow into the burner (WB) is evaluated as

$$WB = WCD - WTC \tag{A-23}$$

where WTC is airflow which is extracted from the compressor discharge to cool the turbine.

Then a test is made to determine if ITER1 equals one. If ITER1 = 1, indicating that this is the first pass through the W_o iteration loop, an initial value is assigned to turbine discharge pressure (PT).

$$PT = 0.35\ PCD \tag{A-24}$$

If ITER1 > 1, the routine goes directly to step 2 since a value for PT has already been calculated in this case.

Turbine inlet airflow is then computed from the steady-state continuity relation

$$WT_{OLD} = WB\ (1 + FAB) \tag{A-25}$$

This is the sum of burner inlet airflow and fuel flow.

Next, the three experimental relations which model burner performance are evaluated. First, the pressure drop across the burner is computed

$$\Delta PB = \frac{KB \cdot WB^2}{PCD}\ (0.771\ TCD - 0.35\ TB) \tag{A-26}$$

where KB is a constant. Pressure losses due to both fluid friction and momentum changes from the addition of heat are included in this expression.

The pressure at the burner discharge (PB) is

$$PB = PCD - \Delta PB \tag{A-27}$$

Next, burner efficiency η_B is evaluated as a function of the parameter PBDTB where

$$PBDTB \stackrel{\Delta}{=} PB\ (TB - TCD) \tag{A-28}$$

Burner efficiency is defined as the portion of the heat of combustion that is available for a gas temperature rise. Finally, burner enthalpy (HB) is determined from the real-gas functional relationship

$$HB = HB\,[FAB,\ TB] \qquad \text{(A-29)}$$

The Figure A-1 flow chart shows that turbine enthalpy drop (ΔHT) is actually calculated between the computation of burner efficiency and burner enthalpy. Turbine enthalpy drop is determined from experimental turbine data, i.e., from $\frac{\Delta HT}{N\sqrt{TB}}$, $\frac{PT}{PB}$, and $\frac{N}{\sqrt{TB}}$. Thus the enthalpy drop is

$$\Delta HT = \frac{\Delta HT}{N\sqrt{TB}} \cdot N \cdot \sqrt{TB} \qquad \text{(A-30)}$$

At this point in the routine, sufficient data are available to recalculate turbine inlet airflow from the heat equation as applied to the burner. The heat equation specifies that under steady flow conditions

$$\Sigma\dot{Q}_{BURNER} = \Sigma(WH)_{BURNER} = 0$$

The amount of heat which enters the burner must equal the heat which exits from the burner. In terms of the parameters previously identified

$$(WH)_{in} = (WH)_{out}$$

or (A-31)

$$WB \cdot HCD + W_f \cdot h_{FUEL} \cdot \eta_B = (WB+W_f) \cdot HB$$

This equation is solved for the term (WB + WF) which is the burner discharge flow. The result is

$$WT_1 = \frac{WB\,(h_{FUEL} \cdot \eta_B - HCD)}{(h_{FUEL} \cdot \eta_B - HB)} \qquad \text{(A-32)}$$

where $WT_1 = (WB + W_f)$ is the burner discharge or turbine inlet airflow. Note that fuel flow does not appear explicitly in this equation, but rather as the difference WT_1 - WB.

Next, the difference between turbine inlet airflow as determined from the heat equation (WT_1) and as determined from the continuity relation (WT_{OLD}) is computed. The result is termed turbine airflow error, WT_{ERROR}.

$$WT_{ERROR} \triangleq |WT_1 - WT_{OLD}| \tag{A-33}$$

The magnitude of this error is the convergence criterion for the fuel flow iteration loop. If $|WT_{ERROR}| \leq 0.0005$, the iteration loop is converged. If $|WT_{ERROR}| > 0.0005$, fuel flow is updated according to the following scheme:

$$\begin{aligned} WT_{OLD} &= 1/2\,(WT_{OLD} + WT_1) \\ WF &= WT_{OLD} - WB \\ FAB &= WT/WB \end{aligned} \tag{A-34}$$

and the routine is returned to step 4. The fuel flow iteration continues until the criterion $|WT_{ERROR}| \leq 0.0005$ is satisfied.

After the fuel flow iteration converges, the airflow out of the turbine is computed. This airflow is called the nozzle airflow, WN.

$$WN = WT_1 + WTC \tag{A-35}$$

It is assumed that the cooling airflow, WTC, is added back into the flow at the turbine discharge.

Next, turbine enthalpy is computed from the equation

$$HT = \frac{WT_1(HB - \Delta HT) + WTC \cdot HCD}{WN} \tag{A-36}$$

Then the steady-state rotor torque relation,

$$\dot{N} = \Sigma_{TORQUE} = 0$$

is used to recalculate burner enthalpy. The airflow-enthalpy change across the compressor is subtracted from the airflow-enthalpy change across the turbine to determine the net rotor torque.

$$\Sigma_{TORQUE} = \Delta(WH)_{TURBINE} - \Delta(SH)_{COMPRESSOR} = 0$$

This equation is solved for a new estimate of burner enthalpy, called HB_R.

$$HB_R = \frac{\Delta(WH)_{CD} + WN \cdot HT - WTC \cdot HCD}{WT_1} \tag{A-37}$$

The difference between burner enthalpy as calculated from the above equation (HB_R) and burner enthalpy as previously determined from the real gas model (HB) is termed burner temperature error.

$$TB_{ERROR} \stackrel{\Delta}{=} HB_R - HB \tag{A-38}$$

A non-zero value of TB_{ERROR} indicates that the burner temperature estimate, TB, is inaccurate. The magnitude of this error is the convergence criterion for the TB iteration loop. If $|TB_{ERROR}| \leq 0.0005$ the iteration is converged; if $|TB_{ERROR}| > 0.0005$ the estimate of burner temperature, TB, is updated and the routine returns to step 3.

The change in TB depends on the algebraic sign of TB_{ERROR}. If HB_R is greater than HB, TB is increased. If HB_R is less than HB, TB is decreased. The magnitude of the change in TB, called ΔTB, is regulated in the routine

such that if the algebraic sign of TB_{ERROR} changes in successive iterations, the step size is halved. This procedure guarantees convergence.

Flow conditions in the exhaust nozzle are computed after the TB iteration is converged. First, the nozzle pressure ratio (PR_N) is evaluated

$$PR_N = \frac{P_8}{PT} \tag{A-39}$$

where P_8 is discharge pressure at the nozzle exit.

The flow condition in the nozzle is determined by the magnitude of PR_N. If $PR_N > 1$, ambient pressure is greater than nozzle pressure and thus zero flow is assumed. If $PR_N < 0.528$, the nozzle is choked and if $0.528 < PR_N < 1$, the nozzle is unchoked. A nozzle coefficient is assigned depending on the flow condition.

$$\begin{aligned}
K_{NOZ} &= 0 \quad \text{if } PR_N > 1, \quad \text{zero flow} \\
K_{NOZ} &= 0.2588 \quad \text{if } PR_N > 0.528, \quad \text{choked flow} \\
K_{NOZ} &= \left(\frac{P_8}{PT}\right)^{\frac{1}{\gamma}} \sqrt{1 - \left(\frac{P_8}{PT}\right)^{\frac{\gamma-1}{\gamma}}} \quad \text{if } 0.528 < PR_N < 1, \text{ unchoked flow}
\end{aligned} \tag{A-40}$$

Next, turbine airflow is recalculated from experimental turbine data which is a correlation of the three parameters $\frac{WT \cdot TB}{N \cdot PB}$, $\frac{PT}{PB}$, $\frac{N}{TB}$. Turbine airflow computed from this data is

$$WT_2 = \left(\frac{WT \cdot TB}{N \cdot PB}\right) \cdot \frac{N \cdot PB}{TB} \tag{A-41}$$

The symbol WT_2 is used to differentiate this airflow from the two expressions for turbine airflow previously obtained, WT_{OLD} and WT_1.

The difference between WT_2 and WT_1 is then computed.

$$PT_{ERROR} \triangleq WT_2 - WT_1 \qquad (A-42)$$

This error is called turbine pressure error because a mismatch between WT_2 and WT_1 indicates that turbine pressure is not correct. The magnitude of this error determines if the iteration on PT is converged. If $|PT_{ERROR}| \leq 0.0005$, the iteration is converged. If $|PT_{ERROR}| > 0.0005$ the estimate of PT is updated and the routine returned to step 2 for another iteration.

The algebraic sign of PT_{ERROR} determines how the value of PT is adjusted. If PT_{ERROR} is positive, the value of PT is increased; and if PT_{ERROR} is negative, PT is decreased. Mechanization of the PT iteration is identical to the TB iteration (refer to Figure A-1 flow chart).

Following the convergence of the PT iteration, the turbine temperature (TT) is evaluated as a function of turbine enthalpy (HT) and fuel-to-air ratio in the turbine (FAT). Turbine temperature is then used to recompute nozzle airflow from the isentropic relation

$$WN_X = \frac{KNA8 \cdot K_{NOZ} \cdot PT \cdot A_8}{\sqrt{TT}} \qquad (A-43)$$

The constant KNA8 is a contraction coefficient which is a function of spool speed. The subscript X on WN is used in this expression to differentiate between the nozzle airflow computed here and the nozzle airflow previously computed from the continuity relation, WN.

The difference between WN_X and WN is then computed

$$W_{ERROR} \triangleq WN_X - WN \qquad (A-44)$$

This error is a measure of the accuracy achieved by the outer loop iteration for inlet airflow, W_o. If $|W_{ERROR}| \leq 0.0005$, the iteration is sufficiently converged. If $|W_{ERROR}| > 0.0005$, the value of W_o is updated and the routine returns to step 1. Inlet airflow, W_o, is increased if W_{ERROR} is positive and decreased if W_{ERROR} is negative. The logic associated with this iteration loop is identical to the logic used in the TB and PT iterations.

Logic for the trim completion switch III is also found in this section of the routine. The switch controls printout of results obtained from intermediate steps in the program. Until all four iteration loops have converged to within the specified tolerances, the value of III is zero. Once the loops have all converged, III is set equal to one and the routine is sent back to the beginning, station 1. Values of the parameters of interest are then printed out during this final pass through the iteration loops.

Dynamic Subroutine

This section of the program computes derivatives with respect to time of spool speed (N) and case temperature (TM) given the following set of initial conditions: compressor inlet pressure and temperature ($P_o T_o$), nozzle discharge pressure (P_8), current spool speed (N), current case temperature (TM), fuel flow (W_f), and geometry control positions (A_8, IGV, BLD).

The structure of this routine closely parallels that of the TRIM routine. Computations begin at the engine inlet and proceed through the engine to the exhaust nozzle. Parameters associated with the compressor section are evaluated first, followed in order by burner, turbine and finally exhaust nozzle parameters.

Initial conditions are specified by the nine input parameters, P_o, T_o, P_8, N, TM, W_f, A_8, IGV, and BLD. Initial estimates of turbine pressure (PT), inlet

airflow (W_o), and burner efficiency (η_B) are also required. Actual values of these three parameters, PT, W_o and η_B, are computed iteratively in the subroutines.

The compressor is modeled by the same set of mathematical relations which are included in the TRIM routine. Inputs to the compressor section include spool speed, inlet parameters W_o, P_o, and T_o, and compressor geometry control positions IGV and BLD. Steady-state pressure and temperature rise maps are used to compute individual stage parameters. The stages are stacked to form the compressor model; i.e., the discharge conditions of one stage are the inlet conditions of the next stage. Flow conditions at the compressor discharge are defined in terms of pressure (PCD), temperature (TCD), airflow (WCD), and enthalpy (HCD).

Steady-state burner performance is modeled by the same three experimental relations which are included in the TRIM routine. Two of these relations are used to compute burner temperature (TEB) and burner pressure (PB). The third relation is used in an iteration loop to determine burner efficiency (η_B).

Thermal capacitance effects are included at the end of the burner section. The rate of change of temperature of the engine case metal is calculated from the equation

$$\dot{T}_M = K_{TM} (TEB - TM) \tag{A-45}$$

where TM is the average temperature of the metal and K_{TM} is a constant of proportionality (a function of thermal conductivity and geometric measurements). The temperature of the gas discharged from the burner (TB) is computed from

$$TB = TEB - K_{TB} \cdot \dot{TM} \tag{A-46}$$

where K_{TB} is a constant similar to K_{TM}. Note that in thermal equilibrium these equations reduce to

$$TEB = TM = TB$$

Turbine and exhaust nozzle performance are also modeled by the steady-state relations which are included in the TRIM routine. These functions relate nozzle airflow (WN), turbine temperature (TT), turbine enthalpy drop ΔHT), and turbine airflow (WT) with spool speed, burner discharge pressure and temperature (TB and PB), nozzle area (A_8), and ambient nozzle pressure (P_8).

Rotor dynamics are considered at the end of the nozzle section. Angular acceleration of the rotor shaft is computed as a function of enthalpy change,

$$\dot{N} = \frac{K_N \cdot [\Delta(WH)_T - \Delta(WH)_{CD}]}{N} \tag{A-47}$$

where $\Delta(WH)_T$ is the airflow $\cdot$ enthalpy change across the turbine, and $\Delta(WH)_{CD}$ is the airflow $\cdot$ enthalpy change across the compressor. K_N is a constant relating rotor speed in radians per second to rotor speed in revolutions per minute.

Inlet airflow (W_o) and turbine discharge pressure (PT) are computed iteratively in the last section of the program. A gradient search procedure, Newton's method, is used to find W_o and PT since they cannot be obtained directly from the model equations.

A flow chart of the DYNAMIC subroutine is presented in Figure A-2. Details of the procedure are discussed in the following paragraphs.

First, the initial conditions P_o, T_o, P_8, N, TM, W_f, A_8, IGV and BLD and initial estimates W_o, PT, and η_E are read in. These variables are obtained either directly from the TRIM routine or from a previous call to this subroutine.

Then the iteration loop counters are initialized. Both ITER1 and ITER2 are set to zero. ITER2 counts the number of outer loop iterations and ITER1 is a loop counter within the gradient search procedure.

Compressor variables are computed in the next section of the program. The compressor model included in this subroutine is identical to the model included in the TRIM routine.

Inputs to the compressor section include inlet conditions W_o, P_o, and T_o and compressor geometry control positions IGV and BLD. Discharge airflow, WCD, pressure, PCD, temperature, TCD, and enthalpy, HCD, are evaluated in the model. Details of the compressor simulation are shown in the Figure A-2 flow chart and discussed in the TRIM routine documentation.

Next burner inlet airflow is computed from the continuity relation

$$WB = WCD - WTC \tag{A-48}$$

where WTC is the airflow which is extracted from the compressor discharge airflow to cool the turbine vanes. The fuel-to-air ratio in the burner is also evaluated,

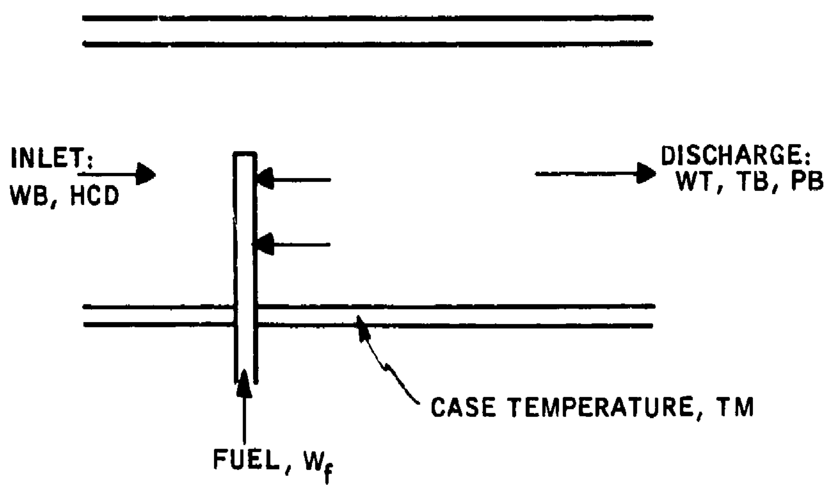
$$FAB = W_f / WB \tag{A-49}$$

Burner enthalpy is calculated from the heat equation.

$$HB = HCD + h_{FUEL} \cdot \eta_{B_0} \cdot FAB \tag{A-50}$$

The term $h_{FUEL} \cdot \eta_{B_0} \cdot FAB$ is the enthalpy increase due to burning of the fuel. The current value of burner efficiency, η_B, is also stored as the variable η_{B_0} in this step.

The time derivative of burner case temperature, $\dot{TM}$, is determined in the next step from the thermal capacitance model:



First, the combustion temperature of the gas is computed as a function of FAB and HB,

$$TEB = TEB\,[FAB,\ HB] \tag{A-51}$$

Then the rate of change of case temperature, $\dot{TM}$, is computed from the heat transfer relation, Equation (A-45):

$$\dot{TM} = K_{TM} \cdot (TEB - TM)$$

The constant K_{TM} is a function of the thermal properties of the case material and the term (TEB - TM) is the temperature gradient at the gas-metal interface. Finally, the temperature of the gas discharged from the burner is computed from Equation (A-46):

$$TB = TEB - K_{TB} \cdot \dot{TM}$$

K_{TB} is a constant in this equation. Note that if the burner is not in thermal equilibrium, i.e., TM $\neq$ TEB, the temperature of the gas discharged from the burner, TB, will not equal the combustion temperature, TEB.

Burner pressure is calculated in the next step.

$$PB = PCD - \frac{K_B \cdot WB^2}{PCD} (0.771\ TCD - 0.085\ TB) \qquad \text{(A-52)}$$

This relation was also used to calculate burner pressure in the TRIM routine.

Then the value of burner efficiency is recalculated from the experimental data relating efficiency to the variables PB, TB and TCD.

$$\eta_B = \eta_B [PB\ (TB - TCD)] \qquad \text{(A-53)}$$

The updated value η_B is compared with the previous value η_{B_o} to determine if the burner simulation is converged. If the error $|\eta_B - \eta_{B_o}|$ is less than E-10, the routine proceeds to the turbine simulation. If $|\eta_B - \eta_{B_o}|$ is greater than E-10, η_{B_o} is replaced by η_B and the routine returns to step 2.

The first parameter calculated in the turbine section is turbine inlet airflow, WT. It is computed from the continuity relation

$$WT = WB + WF \qquad \text{(A-54)}$$

Fuel-to-air ratio in the turbine is also computed at this time.

$$FAT = WF/(WT + WTC) \qquad \text{(A-55)}$$

Note that the turbine cooling airflow, WTC, has been added to turbine inlet airflow in this equation.

Next, turbine inlet airflow is recalculated from the experimental data relating airflow with turbine pressure ratio, burner temperature, and spool speed.

$$WT_{CAL} = \frac{N \cdot PB}{TB} \cdot \left(\frac{WT \cdot TB}{N \cdot PB} \left[\frac{PT}{PB}, \frac{N}{\sqrt{TB}} \right] \right) \tag{A-56}$$

The subscript CAL is attached to this airflow to differentiate between it and turbine airflow computed from the continuity relation.

The difference between WT_{CAL} and WT is then taken.

$$PT_{ERROR} = WT_{CAL} - WT \tag{A-57}$$

The variable name PT_{ERROR} is assigned to this difference because it represents an error in the estimation of turbine discharge pressure, PT. This error is used in the gradient search portion of the program to obtain a better estimate of PT.

Nozzle airflow, WN, is computed from the continuity relation in the next step,

$$WN = WT + WTC \tag{A-58}$$

This parameter is used to evaluate turbine enthalpy, HT, from the heat equation,

$$HT = \frac{WT(HB - \Delta HT) + WTC \cdot HCD}{WN} \tag{A-59}$$

where turbine enthalpy drop, ΔHT, is obtained from the experimental relation

$$\Delta HT = N \cdot \sqrt{TB} \cdot \frac{\Delta HT}{N\sqrt{TB}} \quad \frac{PT}{PB}, \frac{N}{\sqrt{TB}} \tag{A-60}$$

Turbine temperature is then computed from the real gas relation

$$TT = TT\,[FAT,\ HT] \tag{A-61}$$

Airflow in the exhaust nozzle is computed in the next subsection. First, the pressure ratio across the nozzle opening is computed,

$$PR_N \triangleq \frac{P_8}{PT} \tag{A-62}$$

The value of this coefficient determines if the nozzle is choked, unchoked or operating under conditions of reversed flow. This information is conveyed to the nozzle airflow equation through the coefficient K_{NOZ}.

$$K_{NOZ} = 0 \qquad \text{if } PR_N > 1, \qquad \text{reversed flow}$$

$$K_{NOZ} = 0.2588 \qquad \text{if } PR_N < 0.528, \qquad \text{choked flow} \tag{A-63}$$

$$K_{NOZ} = \left(\frac{P_8}{PT}\right)^{\frac{1}{\gamma}} \sqrt{1-\left(\frac{P_8}{PT}\right)^{\frac{\gamma-1}{\gamma}}} \quad \text{if } 0.528 < PR_N < 1, \text{ normal flow}$$

Reversed flow is not allowed in the simulation. If $PR_N > 1$, nozzle airflow is set to zero by assigning $K_{NOZ} = 0$.

After the nozzle coefficient is computed, nozzle airflow is recalculated from the isentropic relation

$$WN_{CAL} = \frac{KNA8 \cdot K_{NOZ} \cdot PT \cdot A_8}{TT} \tag{A-64}$$

This expression is also used in the TRIM routine. The subscript CAL is used to differentiate between nozzle airflow computed from the continuity relation, WN, and airflow computed from this expression, WN_{CAL}.

Next, the difference between WN_{CAL} and WN is calculated

$$W_{ERROR} = WN_{CAL} - WN \tag{A-65}$$

The name W_{ERROR} is assigned to this difference since it represents the error in the estimation of inlet airflow, W_o. This error, together with PT_{ERROR}, is used in the gradient search procedure to obtain better estimates of the parameters W_o and PT.

Rotor acceleration, $\dot{N}$, is computed next from the conservation of angular momentum.

$$\dot{N} = \frac{K_N \cdot [\Delta(WH)_T - \Delta(WH)_{CD}]}{N} \tag{A-66}$$

The symbols $\Delta(WH)_T$ and $\Delta(WH)_{CD}$ represent the airflow · enthalpy changes across the turbine and the compressor respectively. They are defined as

$$\Delta(WH)_T = WT \cdot \Delta HT$$

$$\Delta(WH)_{CD} = HCD \cdot WCD - c_p \cdot T_o \cdot W_o \tag{A-67}$$

$$+ c_p (WBL_3 \cdot TC_3 + WBL_4 \cdot TC_4 + WBL_5 \cdot TC_5)$$

Finally, the errors PT_{ERROR} and W_{ERROR} are interrogated to determine if the outer iteration loop on the parameters PT and W_o is converged. If the magnitudes of both errors are less than the maximum allowable error, e, the iteration is converged and the subroutine returns to the main program. If the test is not passed, new estimates of the parameters PT and W_o are computed by Newton's method and the subroutine starts over at step 1.

In Newton's method the k+1 gradient step is

$$\underline{Z}^{k+1} = \underline{Z}^{k} - (\nabla h_{[\underline{Z}^k]})^{-1} \cdot \underline{h}_{[\underline{Z}^k]} \tag{A-68}$$

where $\underline{Z}$ is the vector of unknowns and $\underline{h}$ is the vector of errors. Thus the k+1 estimate of $\underline{Z}$ is computed from the kth estimate of $\underline{Z}$, the value of the error function $\underline{h}$ evaluated at $\underline{Z}^k$, and the gradient of the error function ∇h evaluated at $\underline{Z}^k$. In terms of the parameters PT, W_o, PT_{ERROR} and W_{ERROR} the vectors $\underline{Z}$, $\underline{h}$ and ∇h are

$$\underline{Z}^T \triangleq \{PT, W_o\}$$

$$\underline{h}^T \triangleq \{PT_{ERROR}, W_{ERROR}\}$$

$$\nabla h \triangleq \begin{bmatrix} \dfrac{\partial PT_{ERROR}}{\partial PT} & \dfrac{\partial PT_{ERROR}}{\partial W_o} \\ \dfrac{\partial W_{ERROR}}{\partial PT} & \dfrac{\partial W_{ERROR}}{\partial W_o} \end{bmatrix} \tag{A-69}$$

Since the partial derivatives in ∇h cannot be computed analytically, they are approximated by finite difference equations in the computer program. For example,

$$\frac{\partial PT_{ERROR}}{\partial PT} = \frac{PT_{ERROR}[PT + \Delta PT, W_o] - PT_{ERROR}[PT - \Delta PT, W_o]}{2\,\Delta PT} \tag{A-70}$$

Thus, both positive and negative perturbations in the unknown variable PT are considered. Similar expressions could be written for the other partial derivatives.

The gradient calculation consists of five intermediate steps. In the first step, the errors in the $\underline{h}$ vector are evaluated, PT_{ERROR} and W_{ERROR}. The partial derivatives with respect to PT, $\partial PT_{ERROR}/\partial PT$ and $\partial W_{ERROR}/\partial W_o$, are computed in the second and third steps. These calculations require two steps because both positive and negative perturbations in PT are considered. The other two partial derivatives, $\partial PT_{ERROR}/\partial W_o$ and $\partial W_{ERROR}/\partial W_o$, are evaluated in the final two steps. New estimates of PT and W_o are also obtained in the last step from the equation

$$\begin{bmatrix} PT_S \\ \\ W_{o_S} \end{bmatrix} = \begin{bmatrix} PT \\ \\ W_o \end{bmatrix} + \begin{bmatrix} \dfrac{\partial PT_{ERROR}}{\partial PT} & \dfrac{\partial PT_{ERROR}}{\partial W_o} \\ \\ \dfrac{\partial W_{ERROR}}{\partial PT} & \dfrac{\partial W_{ERROR}}{\partial W_o} \end{bmatrix}^{-1} \begin{bmatrix} PT_{ERROR} \\ \\ W_{ERROR} \end{bmatrix} \tag{A-71}$$

where the subscript S is used to denote the updated values.

The actual calculations performed in the subroutine are presented in the Figure A-2 flow chart beginning with the computation

ITER1 = ITER1+1

Logic which differentiates between the five steps of the gradient procedure is provided through this variable.

In the first step (ITER1=1), nominal values of the errors PT_{ERROR} and W_{ERROR} are stored under the names F and G. Then the nominal value of PT is increased by the amount ΔPT and the routine is sent back to location number 1.

In the second step (ITER1=2), new values of the errors PT_{ERROR} and W_{ERROR} evaluated for a positive perturbation in PT are stored as FX_+ and GX_+. Then the current value of PT is decreased by the amount $2\Delta PT$ and the routine is sent back to location 1. This is equivalent to decreasing the nominal value of PT by ΔPT.

New values of the errors PT_{ERROR} and W_{ERROR} evaluated for a negative perturbation in PT are stored as FX_- and GX_- in the third step (ITER1=3). The partial derivatives with respect to PT are evaluated from the finite difference approximations,

$$\frac{\partial PT_{ERROR}}{\partial PT} \triangleq FX = \frac{(FX_+ - FX_-)}{2\Delta PT}$$

$$\frac{W_{ERROR}}{PT} \triangleq GX = \frac{(GX_+ - GX_-)}{2\Delta PT} \qquad \text{(A-72)}$$

Then PT is returned to its nominal value by adding ΔPT to the current value, and the nominal value of W_o is increased by ΔW_o. Finally, the routine is sent to location 1.

Partial derivatives with respect to W_o are evaluated in steps four and five in the same manner as derivatives with respect to PT were obtained in steps two and three. The resulting finite difference approximations are

$$\frac{\partial PT_{ERROR}}{\partial W_o} \triangleq FY = \frac{(FY_+ - FY_-)}{2\Delta W_o}$$

$$\frac{\partial W_{ERROR}}{\partial W_o} \triangleq GY = \frac{(GY_+ - GY_-)}{2\Delta W_o} \qquad \text{(A-73)}$$

These partial derivatives, together with the nominal errors F and G, are then used to compute the incremental gradient step defined by

$$\Delta PT_S = \frac{(-F \cdot GY + G \cdot FY)}{D}$$

$$\Delta W_{o_S} = \frac{(-G \cdot FX + F \cdot GX)}{D} \tag{A-74}$$

where ΔPT_S is the incremental change in PT and ΔW_{OS} is the incremental change in W_o. The symbol D represents the determinant of the partial derivative matrix

$$D = FX \cdot GY - GX \cdot FY \tag{A-75}$$

Before the g adient step defined by the increments ΔPT_S and ΔW_{OS} is taken, the magnitude of the increments is tested and reduced, if necessary. First the magnitude of ΔPT_S is tested.

$$|\Delta PT_S| < 2\Delta PT$$

If this test is failed, the magnitudes of both ΔPT_S and ΔW_{OS} are reduced by the ratio, $2\Delta PT/|\Delta PT_S|$.

This adjustment reduces only the magnitude of the gradient step; the gradient direction is preserved. If $|\Delta PT_S|$ is smaller than $2\Delta PT$, this adjustment is bypassed.

The magnitude of ΔW_{OS} is also tested in a similar manner. If $|\Delta W_{OS}|$ is greater than $2\Delta W_o$, the gradient step is further reduced by the ratio, $2\Delta W_o/|\Delta W_{OS}|$. If $|\Delta W_{OS}|$ is smaller than $2\Delta W_o$, this magnitude adjustment is bypassed.

Finally, the current values of PT and W_o are updated,

$$PT = PT + \Delta PT_S$$
$$W_o = W_o + \Delta W_{o_S} \qquad (A-76)$$

the counter ITER1 is reinitialized, and the routine is started anew from location number 1.

Linearizer

This section of the program extracts linear models from the nonlinear engine model. Inputs to the program include steady-state spool speed (N), steady-state engine case temperature (TM), fuel flow (W_f), geometry control positions (A_8, IGV, BLD), inlet pressure and temperature (P_o, T_o), exhaust nozzle discharge pressure (P_8), and perturbation step size (DPERT). The nonlinear engine model is linearized about the equilibrium operating point defined by the first nine input parameters. The tenth input parameter (DPERT) determines the magnitude of the perturbations considered in constructing the linear model.

The linear models obtained are of the form

$$\Delta\dot{x} = F\Delta x + G1\Delta u + G2\Delta\eta$$
$$\Delta r = H\Delta x + D1\,\Delta u + D2\,\Delta\eta \qquad (A-77)$$

where x is the state vector, u is the control vector, η is the disturbance vector, r is the response vector and F, G1, G2, H, D1, D2 are coefficient matricies. The Δ symbol is used in these equations to emphasize the fact that the linear models represent perturbations from equilibrium operating conditions.

Engine variables included in the x, u, η, or r vectors are:

$$
\begin{aligned}
x &= N \text{ (spool speed)} \\
&\quad TM \text{ (engine case temperature)} \\
u &= WF \text{ (fuel flow)} \\
&\quad IGV \text{ (inlet guide vane angle)} \\
&\quad A_8 \text{ (exhaust area)} \\
&\quad BLD \text{ (compressor bleed position)} \\
\eta &= P_c \text{ (inlet pressure)} \\
&\quad T_o \text{ (inlet temperature)} \\
&\quad P_8 \text{ (exhaust nozzle discharge pressure)} \\
r &= PCD \text{ (compressor discharge pressure)} \\
&\quad PT \text{ (turbine discharge pressure)} \\
&\quad TB \text{ (burner temperature)} \\
&\quad TT \text{ (turbine discharge temperature)}
\end{aligned}
\tag{A-78}
$$

It should be noted that additional variables can be added to the response vector by the user, if desired. The x, u, and η vectors cannot be enlarged as they already contain all the states, controls, and disturbances which are included in the nonlinear engine model.

Coefficients in the matrices F, G1, G2, H, D1 and D2 are computed in the program by a procedure based on the linearization method described in Reference A-2. Briefly, the procedure consists of expanding the nonlinear engine model represented by the nonlinear matrix functions f and h,

$$
\begin{aligned}
\dot{x} &= f(x,u,\eta) \\
r &= h(x,u,\eta)
\end{aligned}
\tag{A-79}
$$

in a Taylor series about the equilibrium operating point defined by the steady-state input parameters N, TM, WF, A_8, IGV, BLD, P_o, T_o and P_8. This equilibrium point is denoted as (x_o, u_o, η_o). Note that substitution of these variables, x_o, u_o, and η_o, into the nonlinear system equations gives

$$
\begin{aligned}
f(x_o, u_o, \eta_o) &= \dot{x}_o = 0 \\
h(x_o, u_o, \eta_o) &= r_o
\end{aligned}
\tag{A-80}
$$

The result of the Taylor series expansion is

$$
\begin{aligned}
f(x, u, \eta_o) - f(x_o, u_o, \eta_o) &= \frac{\partial f}{\partial x}(x_o, u_o, \eta_o)\Delta x + \frac{\partial f}{\partial u}(x_o, u_o, \eta_o)\Delta u \\
&\quad + \frac{\partial f}{\partial \eta}(x_o, u_o, \eta_o)\Delta \eta \\
h(x, u, \eta_o) - h(x_o, u_o, \eta_o) &= \frac{\partial h}{\partial x}(x_o, u_o, \eta_o)\Delta x + \frac{\partial h}{\partial u}(x_o, u_o, \eta_o)\Delta u \\
&\quad + \frac{\partial h}{\partial \eta}(x_o, u_o, \eta_o)\Delta \eta
\end{aligned}
\tag{A-81}
$$

which is equivalent to the linear representation of Equations (A-77) if the following definitions are made.

$$
\begin{aligned}
\Delta\dot{x} &\triangleq \dot{x} - \dot{x}_o = f(x, u, \eta) - f(x_o, u_o, \eta_o) \\
\Delta r &\triangleq r - r_o = h(x, u, \eta) - h(x_o, u_o, \eta_o) \\
F &\triangleq \frac{\partial f}{\partial x}(x_o, u_o, \eta_o) \\
G1 &\triangleq \frac{\partial f}{\partial u}(x_o, u_o, \eta_o) \\
G2 &\triangleq \frac{\partial f}{\partial \eta}(x_o, u_o, \eta_o)
\end{aligned}
\tag{A-82}
$$

$$H \triangleq \frac{\partial h}{\partial x}(x_o, u_o, \eta_o)$$

$$D1 \triangleq \frac{\partial h}{\partial u}(x_o, u_o, \eta_o) \qquad \text{(A-82)}$$

$$D2 \triangleq \frac{\partial h}{\partial \eta}(x_o, u_o, \eta_o)$$

Thus the coefficient matricies are actually matricies of partial derivatives evaluated at the equilibrium point. For example, the F matrix is

$$F = \begin{bmatrix} \frac{\partial f_1}{\partial x_1}(x_o, u_o, \eta_o) & \frac{\partial f_1}{\partial x_2}(x_o, u_o, \eta_o) \ldots & \frac{\partial f_1}{\partial x_\eta}(x_o, u_o, \eta_o) \\ \frac{\partial f_2}{\partial x_1}(x_o, u_o, \eta_o) & \frac{\partial f_2}{\partial x_2}(x_o, u_o, \eta_o) \ldots & \frac{\partial f_2}{\partial x_\eta}(x_o, u_o, \eta_o) \\ \vdots & & \\ \frac{\partial f_\eta}{\partial x_1}(x_o, u_o, \eta_o) & \frac{\partial f_\eta}{\partial x_2}(x_o, u_o, \eta_o) \ldots & \frac{\partial f_\eta}{\partial x_\eta}(x_o, u_o, \eta_o) \end{bmatrix}$$

(A-83)

where n is the dimension of the state vector, x.

Written in terms of engine variables, this matrix is

$$F = \begin{bmatrix} \frac{\partial \dot{N}}{\partial N}(x_o, u_o, \eta_o) & \frac{\partial \dot{N}}{\partial TM}(x_o, u_o, \eta_o) \\ \frac{\partial \dot{TM}}{\partial N}(x_o, u_o, \eta_o) & \frac{\partial \dot{TM}}{\partial TM}(x_o, u_o, \eta_o) \end{bmatrix} \qquad \text{(A-84)}$$

Similar expressions could be written for the other coefficient matrices.

Since the partial derivatives in these matrices cannot be evaluated analytically, they are computed from finite difference approximations in the computer program. The method is illustrated below for the (1, 1) element in the F matrix.

$$\frac{\partial f_1}{\partial x_1}(x_o, u_o, \eta_o) = \frac{f_1(x_{1_o} + \Delta x_1, x_{2o}, \ldots x_{\eta_o}, u_o, \eta_o) - f_1(x_{1_o} - \Delta x_1, x_{2o}, \ldots x_{\eta_o}, u_o, \eta_o)}{2\Delta x_1} \tag{A-85}$$

Thus the procedure involves evaluating the nonlinear-dependent function [$f_1(x, u, \eta)$ in the example] for small perturbations in the independent variable (ΔX_1) about the equilibrium point (x_o, u_o, η_o). Both positive and negative perturbations in the independent variable are considered. The results are averaged to compute the final answer.

In the notation used in the computer program, the partial derivatives associated with the coefficient matrices are denoted as

$$\frac{\partial DX_i}{\partial X_j} = \frac{DX2_i - DX1_i}{2\Delta X_j} \tag{A-86}$$

where

$$DX^T = (\dot{N}, \dot{TM}, PCD, PT, TB, TT)$$

$$X^T = (N, TM, WF, IGV, A_8, BLD, P_o, T_o, P_8)$$

Thus the engine variables associated with the nonlinear functions f and h (i.e., time derivatives of the states and responses) are lumped together in the DX vector. The independent variables (i.e., states, controls, and disturbances) are lumped together in the X vector. The symbol DX2 is used in these equations to denote the DX vector evaluated for a positive perturbation in X_j. Similarly, DX1 denotes the DX vector evaluated for a negative perturbation in X_j.

computations in the program proceed in the following order. First, all the derivatives with respect to X_1 are computed,

$$\frac{\partial DX_i}{\partial X_1} \quad i = 1, 2, \ldots NXR$$

where NXR is the dimension of the DX vector. Then all the derivatives with respect to X_2 are computed,

$$\frac{\partial DX_i}{\partial X_2} \quad i = 1, 2, \ldots NXR$$

This procedure continues until all the derivatives have been computed. The last set evaluated is

$$\frac{\partial DX_i}{\partial X_{NXUE}} \quad i = 1, 2, \ldots NXR$$

where NXUE is the dimension of the X vector.

A flowchart of the linearization program is presented in Figure A-3. This flowchart corresponds to the portion of the fortran listing beginning at statement number 511 in the main program (see listing in Table A-2).

First the parameters N, TM, W_f, IGV, A_8, BLD, P_o, T_c and P_8 specifying the operating point are input. These variables are obtained from the TRIM section of the main program.

Then the perturbation step size DPERT is read in. The units on DPERT are percent.

Next the integer variable J which corresponds to the subscript j in Equation (A-86) is initialized. It is set to zero.

Then nominal values of the variables in the DX vector are computed in subroutine DYNAMIC. The nominal values obtained are stored in the vector DXN.

In the next step the value of J is increased by one. This means that the partial derivatives with respect to X_1 are to be computed first.

Values of the variables in the DX vector are recalculated for a negative perturbation in X_j, in the following steps. However, before the actual calculations are made, the variable X_j is tested to determine if it is zero. A zero value of X_j implies that a negative perturbation step in X_j cannot be taken, since all of the variables in the X vector must always be positive. Thus if $X_j = 0$, the calculations for a negative perturbation in X_j are bypassed. This condition will be discussed later.

If X_j is nonzero, a negative perturbation in X_j is computed from the relation,

$$\begin{aligned} \mathrm{PERT} &= X_j \cdot \mathrm{DPERT} \\ X_j &= X_j - \mathrm{PERT} \end{aligned} \tag{A-87}$$

Then new values of the variables in the DX vector are calculated in subroutine DYNAMIC. The new values are stored in the vector DX1 and the vector DX is reloaded with the nominal values stored in DXN. Finally, the independent variable X_j is restored to its nominal value by adding PERT back on X_j.

$$X_j = X_j + \mathrm{PERT}$$

At this point the values of variables in the DX vector have been computed for a negative perturbation in X_j. In the next steps the variables in the DX vector are recomputed for a positive perturbation in X_j. However, before these calculations can be made, the value of X_j is again tested. This time X_j is tested to determine if its value is close to one, i.e., if $|X_j-1|$ is less than PERT.

The condition $X_j = 1$ is important because two of the independent variables, IGV and BLD, are scaled to be in the range 0 - 1.0. Thus if X_j corresponds to one of these variables (J = 4 or 6) and X_j is one, then a positive perturbation in X_j cannot be computed since it would give $X_j > 1$. In this case the calculations for a positive perturbation in X_j are bypassed. It should be noted that this test does not affect the other independent variables since they are always much greater than one. The calculations performed if $|X_j - 1|$ is less than PERT will be discussed later.

If $|X_j - 1|$ is greater than PERT, then a positive perturbation in X_j is calculated,

$$X_j = X_j + \text{PERT}$$

Values of the variables in the DX vector are recomputed in subroutine DYNAMIC. The results are stored in DX2 and the vector DX is reloaded with nominal values stored in DXN. Finally, X_j is restored to its nominal value by subtracting PERT from X_j.

$$X_j = X_j - \text{PERT}$$

At this point if both the tests on X_j,

$$X_j = 0 \quad \text{and} \quad |X_j - 1| < \text{PERT}$$

were failed, the values of the variables in the DX vector for a negative perturbation in X_j are stored in DX1 and the values of the variables for a positive perturbation in X_j are stored in DX2. In this case the values of the partial derivatives with respect to X_j are computed from the finite difference equation,

$$\frac{\partial DX_i}{\partial X_j} = \frac{DX2_i - DX1_i}{2\ PERT} \qquad i = 1, 2, \ldots NXR \tag{A-88}$$

However, if either of the tests on X_j were passed, then the partial derivatives must be calculated from a different equation because only one of the vectors DX1 or DX2 can be computed.

First consider the case $X_j=0$. In this case only positive perturbations in X_j can be computed. Thus in the calculations beginning at station 3, first a positive perturbation in X_j is computed from

$$PERT = DPERT$$

$$X_j = X_j + PERT$$

(Note that a perturbation in X_j cannot be computed from $PERT = X_j \cdot DPERT$ because $X_j=0$.) Then the values of the variables in the DX vector are computed and stored in DX2. Next, X_j is restored to its nominal value

$$X_j = X_j - PERT$$

and finally the partial derivatives with respect to X_j are computed from the one-sided finite difference equation

$$\frac{\partial DX_i}{\partial X_j} = \frac{DX2_i - DXN_i}{PERT} \qquad i=1, 2, \ldots NXR \tag{A-89}$$

Similarly, in the case $|X_j - 1| < PERT$ (corresponding to station 4) the partial derivatives are calculated from the one-sided finite difference equation

$$\frac{\partial DX_i}{\partial X_j} = \frac{DXN_i - DX1_i}{PERT} \qquad i=1,2,\ldots NXR \tag{A-90}$$

since values of DX2 cannot be obtained.

After the partial derivatives with respect to X_j have been calculated, control of the routine is transferred to station 2. The variable J is tested to determine if all the partial derivatives have been computed (J=NXUE). If J is less than NXUE the routine returns to station 1 to compute the partial derivatives with respect to X_{j+1}. If J=NXUE, the linearization procedure is finished.

Input Data

The input data required to run the linearization program are described in this subsection. Two groups of data are necessary, the program control group and the component description group.

The program control group includes parameters which define the nominal operating condition for the engine and parameters which control the linearization procedure. This information is input on the four data cards identified below, cards A-E.

Card A

(1) ERROR — This parameter determines the accuracy of the iterations in subroutine DYNAMIC

Card B

(1)	NX	Dimension of the state vector
(2)	NU	Dimension of the control vector
(3)	NE	Dimension of the disturbance vector
(4)	NR	Dimension of the response vector
(5)	DPERT	Perturbation step size used in the LINEARIZATION routine

Card C

(1)	N	Nominal value of spool speed
(2)	WINGS	Initial guess for inlet airflow in the TRIM routine
(3)	SPLC	Rotor torque load
(4)	IGV	Inlet guide vane position
(5)	BLD	Compressor bleed position

Card D

(1)	P_o	Compressor inlet pressure
(2)	T_o	Compressor inlet temperature

The component description group consists of tabulated experimental data which models the steady-state operating characteristics of the engine components. This data is stored on magnetic tape and read into dummy arrays at the beginning of the program. Two function subroutines, FUN1 and FUN2, are used in the program to interpolate between the data points.

The experimental functions contained in this data group are presented in Tables A-3a through A-3x and identified below.

Table Number	Function ID	Experimental Function
A-3a	F11	ABLB = f(BVOB)
A-3b	F12	IGVPR = $F(N/N_{max})$
A-3c	F13	OGVPR = $f(N/N_{max})$
A-3d	F15	$\psi_2{}^P = f(\phi_2)$
A-3e	F16	$\psi_2{}^T = f(\phi_2)$
A-3f	F17	$\psi_3{}^P = f(\phi_3)$
A-3g	F18	$\psi_3{}^T = f(\phi_3)$
A-3h	F19	$\psi_4{}^P = f(\phi_4)$
A-3i	F110	$\psi_4{}^T = f(\phi_4)$
A-3j	F111	$\psi_5{}^P = f(\phi_5)$
A-3k	F112	$\psi_3{}^T = f(\phi_5)$
A-3l	F113	$\psi_6{}^P = f(\phi_6)$
A-3m	F114	$\psi_6{}^T = f(\phi_6)$
A-3n	F115	$\psi_7{}^P = f(\phi_7)$
A-3o	F116	$\psi_7{}^T = f(\phi_7)$
A-3p	F117	$\psi_8{}^P = f(\phi_8)$
A-3q	F118	$\psi_8{}^T = f(\phi_8)$
A-3r	F119	$\eta_B = f[PB \cdot (TB\text{-}TCD)]$
A-3s	F120	KWB = $f(N/N_{max})$
A-3t	F1	BVOB = $f(N/N_{max}, T_o)$

Table Number	Function ID	Experimental Function
A-3u	F2	$\psi_2^{P} = f(\phi_2, \text{IGV})$
A-3v	F3	$\frac{WT \cdot TB}{N \cdot PB} = f(\frac{PT}{PB}, \frac{N}{\sqrt{TB}})$
A-3w	F4	$\frac{\Delta HT}{N\sqrt{TB}} = f(\frac{PT}{PB}, \frac{N}{\sqrt{TB}})$
A-3x	F5	$\psi_2^{T} = f(\phi_2, \text{IGV})$

Nominal schedules for the two compressor geometry controls are contained in functions F1 and F11. F1 gives the nominal setting for the IGV (BVOB) as a function of spool speed and compressor inlet temperature. F11 gives the nominal setting for the BLD (ABLB) as a function of BVOB. These actuator schedules were obtained from the NASA component model (Reference A-1). They were not used in the linearization program. Nominal settings for the IGV and BLD are read in on card C of the program control group.

Functions F12 and F13 are correlations of inlet guide vane pressure ratio and outlet guide vane pressure ratio with spool speed.

Pressure and temperature rise coefficients for compressor stages 2 through 8 are contained in functions F15 - F118. These coefficients are functions of a single variable, the flow coefficient ϕ_i.

Pressure and temperature rise coefficients for the first compressor stage are given by functions F2 and F5.

The coefficients for this stage are functions of both flow coefficient ϕ_1 and inlet guide vane position.

Burner efficiency is presented as a function of the parameter PB · (TB-TCD) in F119 where PB is burner pressure, TB is burner temperature, and TCD is compressor discharge temperature.

The constant KWB is determined as a function of spool speed in F120. This constant is used to determine the pressure loss in the burner.

The function F3 and F4 contain steady-state turbine performance data. The parameter WT · TB/N · PB where WT is turbine airflow is given as a function of turbine pressure ratio and the parameter $N/\sqrt{TB}$ in F3. Turbine enthalpy drop ΔHT divided by $N \cdot \sqrt{TB}$ is given as a function of the same two parameters, PT/PB and $N/\sqrt{TB}$, in F4.

NONLINEAR ENGINE SIMULATION

The nonlinear engine simulation program is discussed in this subsection. This program is a fortran version of the NASA component model of Reference A-1. A Fortran listing of the program is presented in Table A-1. A listing of the reduced-order component model is presented in Table A-2.

The function of this program is to simulate the transient response of the engine to changes in full flow, exhaust area, inlet guide vane position and compressor bleed position.

A flowchart of the program is presented in Figure A-4. Computations performed in the program are summarized in the following paragraphs. A detailed description of the software is contained in Reference A-1 and in Section II, Volume I of this report.

First, nominal values of spool speed (N), geometry control positions (A_8, IGV, BLD), compressor inlet pressure and temperature (P_o, T_o), nozzle

discharge pressure (P_8) and rotor torque load (SPLC) are read in. These parameters define the nominal operating condition for the engine.

A steady-state trim point corresponding to these nominal input parameters is computed next. The fuel flow required to maintain nominal spool speed is calculated in addition to initial values of all the engine states X(o) and responses r(o). It should be noted that the section of the program which performs these calculations is identical to the TRIM routine included in the linearization program. A detailed discussion of the TRIM routine is included in the documentation of the linearization program.

Next the control positions u(T) defining the transient to be simulated are read in. The u vector includes fuel flow, exhaust area, inlet guide vane position and compressor bleed position.

The time increment ΔT and simulation stop time FINTIME are defined in the following step. Then time is initialized and the time corresponding to the first integration step is computed.

$$T = T + \Delta T$$

Engine dynamics are computed in the next two steps from the nonlinear engine model contained in subroutine DYNAMIC. This nonlinear model is described in detail in Section II, Volume I of this report. Time derivatives of the engine states are computed from the nonlinear function f,

$$\dot{x}(T) = f[x(T), r(T), u(T)]$$

and updated values of the responses are computed from the nonlinear function h

$$r(T + \Delta T) = h[x(T), r(T), u(T)]$$

The derivatives are then integrated with a four point Runge Kutta integration routine to determine the value of the states at time T + ΔT.

$$x(T + \Delta T) = x(T) + \int_{T}^{T+\Delta T} \dot{x}(T)dT$$

In the final step in the program, the current value of time is compared with the stop time. If T ≥ FINTIME, the program exits from the integration loop. If T < FINTIME, the routine returns to station 1 for an additional integration step.

Table A-1. Nonlinear Engine Simulation Program

```
AFORTRAN LS,C8                                                              A=00
      DIMENSION IGV(42),A(20),PV(20),TV(20),YY1(14),XX1(17),ZZ1(196)
      DIMENSION L(20),V(20),KGAL(20),KVOL(20),KNR(8),RAD(8),KRAD(8)
      DIMENSION KA(30)
      DIMENSION THV(20),WD(20),WV(20),KBLD(8),DPRB(14)
      COMMON/TDATA/TIME,DT,ISTEP,NICOT
      COMMON/DATA/X(39),U(3),ETA(3),DXN(40),DX(40),DXT(40),CLM(40),
     1KVOLIG,KGALIG,KVOLOG,KGALOG,RTHO,ABL,KOGV,WTC,KVOLCD,KGALCD,TR,KWB
     2,KGALB,KVOLB,HT,TT,PT,K4,K2,WT,HCD,PO,WN,KNA8,KSPEED,KFIGV,K3,IGVP
     3R,TVO
      REAL ICTWVO,ICWVO
      REAL K5,K8,NC1,ICN,NC1N,IGVPR,IGV,K1,K3,K4,K6,K7,L,KGAL,KVOL
      REAL KVOLOG,KGALOG,KVOLCD,KGALCD,KGALB,KWB,KVOLB,KVOLT,KSPEED
      REAL KFIGV,NCX,KNR,KRAD,KA,KOGV,KNA8,NRTTB,ICPVO,ICWDO,ICWD1,ICWV1
      REAL ICTWV1,ICWD2,ICWV2,ICTWV2,ICWD3,ICWV3,ICTWV3,ICWD4,ICWV4
      REAL ICTWV4,ICWD5,ICWV5,ICTWV5,ICWD6,ICWV6,ICTWV6,ICWD7,ICWV7
      REAL ICTWV7,ICWD8,ICWV8,ICTWV8,ICTWOG,ICWOGV,ICWDOG,ICTWCD,ICWCD
      REAL ICWDCD,ICWB,ICPB,ICHB,ICRT,ICRHT,ICWFQP,NC2,NC3,NC4,NC5,NC6
      REAL NC7,NC8,NDEMD,ITER,IMPL,INTGRL,KIC
      REAL KA8,ICWDOG,N,NDT
      REAL KBLD,K2,NRAT,KGALIG,KVOLIG
      EQUIVALENCE (ICWDO,WDO,X(1 )),(ICWVO,WVO,X(2 )),(ICTWVO,TWVO,X(3 )
     1            ),(ICWD1,WD1,X(4 )),(ICWV1,WV1,X(5 )),(ICTWV1,TWV1,X(6 )
     2            ),(ICWD2,WD2,X(7 )),(ICWV2,WV2,X(8 )),(ICTWV2,TWV2,X(9 )
     3            ),(ICWD3,WD3,X(10)),(ICWV3,WV3,X(11)),(ICTWV3,TWV3,X(12)
     4            ),(ICWD4,WD4,X(13)),(ICWV4,WV4,X(14)),(ICTWV4,TWV4,X(15)
     5            ),(ICWD5,WD5,X(16)),(ICWV5,WV5,X(17)),(ICTWV5,TWV5,X(18)
     6            ),(ICWD6,WD6,X(19)),(ICWV6,WV6,X(20)),(ICTWV6,TWV6,X(21)
     7            ),(ICWD7,WD7,X(22)),(ICWV7,WV7,X(23)),(ICTWV7,TWV7,X(24)
     8            ),(ICWD8,WD8,X(25)),(ICWV8,WV8,X(26)),(ICTWV8,TWV8,X(27)
     9     ),(ICWDOG,WDOG,X(28)),(ICWOGV,WOGV,X(29)),(ICTWOG,TWOG,X(30))
     A      ,(ICWDCD,WDCD,X(31)),(ICWCD,WCD,X(32)),(ICTWCD,TWCD,X(33))
     B                         ,(ICWB,WB,X(34)),(ICPB,PB,X(35))
     C      ,(ICHB,HB,X(36)),(ICRHT,RHT,X(37)),(ICRT,RT,X(38))
     D      ,(ICN,N,X(39)),(WF,U(1)),(BVB,U(2)),(A8,U(3)),(P2,ETA(1))
     E      ,(T2,ETA(2)),(P8,ETA(3))
      EQUIVALENCE (WDODT  ,DX(1 )),(WVODT  ,DX(2 )),(TWVODT ,DX(3 )),
     1            (WD1DT  ,DX(4 )),(WV1DT  ,DX(5 )),(TWV1DT ,DX(6 )),
     2            (WD2DT  ,DX(7 )),(WV2DT  ,DX(8 )),(TWV2DT ,DX(9 )),
     3            (WD3DT  ,DX(10)),(WV3DT  ,DX(11)),(TWV3DT ,DX(12)),
     4            (WD4DT  ,DX(13)),(WV4DT  ,DX(14)),(TWV4DT ,DX(15)),
     5            (WD5DT  ,DX(16)),(WV5DT  ,DX(17)),(TWV5DT ,DX(18)),
     6            (WD6DT  ,DX(19)),(WV6DT  ,DX(20)),(TWV6DT ,DX(21)),
     7            (WD7DT  ,DX(22)),(WV7DT  ,DX(23)),(TWV7DT ,DX(24)),
     8            (WD8DT  ,DX(25)),(WV8DT  ,DX(26)),(TWV8DT ,DX(27)),
     9            (WDOGDT ,DX(28)),(WOGVDT ,DX(29)),(TWOGDT ,DX(30)),
     A            (WDCDDT ,DX(31)),(WCDDT  ,DX(32)),(TWCDDT ,DX(33)),
     B                             (WBDT   ,DX(34)),(PBDT   ,DX(35)),
     C            (HBDT   ,DX(37)),(RHTDT  ,DX(38)),(RTDT   ,DX(39)),
     D            (NDT    ,DX(39))
      REWIND 3
 8099 CONTINUE
      RND1=0.
      RND2=0.
      READ(5,8030)NX,NU,NE,DPERT
 8030 FORMAT(3I2,G12.5)
      REWIND 7
      DATA (DPRB(I),I=1,14)/.60,7.26E-4,.70,7.07E-4,.80,6.98E-4,.85,6.96E
     1-4,.90,6.96E-4,.97,6.96E-4,1.0,7.38E-4/
      DATA (KBLD(I),I=1,8)/2.0,1.1025,1.0572,1.0411,3.0,/
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      DATA (KGAL(I),I=1,8)/25542.,27942.,27247.,26407.,24084.,21872.,221
     155.,22439./
      DATA (KVAL(I),I=1,8)/1.9107,3.3[illegible]11,4.9797,7.0839,9.3047,11.2953,13
     1.7272,15.1219/
      DATA (TV(I),I=1,20)/5*1600.,15*518.7/
      DATA (TWV(I),I=1,20)/20*10./
      DATA (WC(I),I=1,20)/20*30./
      DATA (WV(I),I=1,20)/20*.01/
      READ(7)(IGV(I),I=1,18)
      F11 =FN1SET(1,IGV   ,9,1,1)
      READ(7)(IGV(I),I=1,38)
      F14 =FN1SET(4,IGV ,19,4,5)
      READ(7)(IGV(I),I=1,20)
      F12 =FN1SET(2,IGV,10,2,2)
      READ(7)(IGV(I),I=1,18)
      F13 =FN1SET(3,IGV,9, 3,3)
      READ(7)(IGV(I),I=1,40)
      F15 =FN1SET(5,IGV   ,20,6,7)
      READ(7)(IGV(I),I=1,42)
      READ(5,877)(IGV(I),I=1,42)
  877 FORMAT(10F8.4)
      F16 =FN1SET(6,IGV ,21,8,9)
      READ(7)(IGV(I),I=1,34)
      F17 =FN1SET(7,IGV   ,17,10,11)
      READ(7)(IGV(I),I=1,38)
      READ(5,877)(IGV(I),I=1,38)
      F18 =FN1SET(8,IGV ,19,12,13)
      READ(7)(IGV(I),I=1,36)
      F19 =FN1SET(9,IGV   ,18,14,15)
      READ(7)(IGV(I),I=1,36)
      IGV(3)=.53
      READ(5,877)(IGV(I),I=1,40)
      F110=FN1SET(10,IGV,20,16,17)
      READ(7)(IGV(I),I=1,32)
      F111=FN1SET(11,IGV   ,16,18,19)
      READ(7)(IGV(I),I=1,32)
      READ(5,877)(IGV(I),I=1,36)
      F112=FN1SET(12,IGV,18,20,21)
      READ(7)(IGV(I),I=1,26)
      F113=FN1SET(13,IGV   ,13,22,23)
      READ(7)(IGV(I),I=1,26)
      READ(5,877)(IGV(I),I=1,26)
      F114=FN1SET(14,IGV ,13,24,25)
      READ(7)(IGV(I),I=1,30)
      F115=FN1SET(15,IGV   ,15,26,27)
      READ(7)(IGV(I),I=1,24)
      READ(5,877)(IGV(I),I=1,26)
      F116=FN1SET(16,IGV,13,28,29)
      READ(7)(IGV(I),I=1,30)
      F117=FN1SET(17,IGV   ,15,30,31)
      READ(7)(IGV(I),I=1,32)
      READ(5,877)(IGV(I),I=1,32)
      F118=FN1SET(18,IGV ,16,32,33)
      READ(7)(IGV(I),I=1,28)
      F119=FN1SET(19,IGV ,14,34,35)
      READ(7)(IGV(I),I=1,26)
      F120=FN1SET(20,DPRB,7,36,37)
      READ(7)(IGV(I),I=1,40)
      F121=FN1SET(21,IGV    ,20,38,39)
       READ(7)(A(I),I=1,20)
       READ(7)(L(I),I=1,20)
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      READ(7)(V(I),I=1,20)
      READ(7)(IGV (I),I=1,20)
      READ(7)(IGV (I),I=1,20)
      READ(7)(RAD(I),I=1,8)
      READ(7)(KRAD(I),I=1,8)
      READ(7)(FV(I),I=1,20)
      READ(7)(IGV(I),I=1,20)
      READ(7)(YY1(I),I=1,5)
      READ(7)(XX1(I),I=1,13)
      READ(7)(ZZ1(I),I=1,65)
     F1= FN2SET(1,XX1,YY1,ZZ1,13,5,1,2)
      READ(7)(KA(I),I=1,30)
      READ(7)(YY1(I),I=1,4)
      READ(7)(XX1(I),I=1,17)
      READ(7)(ZZ1(I),I=1,68)
     F2 = FN2SET(2,XX1,YY1,ZZ1,17,4,3,4)
      READ(7)(YY1(I),I=1,14)
      READ(7)(XX1(I),I=1,14)
      READ(7)(ZZ1(I),I=1,196)
      DO 9773 I=1,43
      IJ=196-I
      JJ=IJ+1
 9773 ZZ1(JJ)=ZZ1(IJ)
      ZZ1(148)=.0545
      WRITE(9,1602)
      WRITE(9,1601)(YY1(I),I=1,14)
      WRITE(9,1603)
      WRITE(9,1601)(XX1(I),I=1,14)
      WRITE(9,1603)
      WRITE(9,1601)(ZZ1(I),I=1,196)
      WRITE(9,1602)
      F3 = FN2SET(3,XX1,YY1,ZZ1,14,14,5,6)
       READ(7)(YY1(I),I=1,14)
       READ(7)(XX1(I),I=1,14)
       READ(7)(ZZ1(I),I=1,196)
 1601 FORMAT(13F9.4)
 1602 FORMAT(1H1)
 1603 FORMAT(//)
      ZZ1(94)=.0951
      F4 = FN2SET(4,XX1,YY1,ZZ1,14,14,7,8)
      READ(5,877)(YY1(I),I=1,4)
      READ(5,877)(XX1(I),I=1,17)
      READ(5,877)(ZZ1(I),I=1,68)
      F5=FN2SET(5,XX1,YY1,ZZ1,17,4,9,10)
C
C SET PARAMETERS
C
      WAR=0
      NSSP=1
      TIGS=1700.
      READ(5,8066)NRAT,AB,TBGS,WINGS,FABGS,SPLC
 8066 FORMAT(6G12.5)
      WRITE(9,8066) NRAT,AB,TBGS,WINGS,FABGS,SPLC
      P2=14.7
      T2=518.7
      WDEL=.1
      K1 = 3.14159/360.
      K2=7.*32.17*5.*35/(K1*K1)
      K3=SQRT(518.7)
      K4=(53.35*12.)/1760C.
      KSALIG=51.37.
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      KVGLIG=3.31
      KGALAG = 2243.
      KVGLAG = 15.11
      KGALCD = 6730.
      KVGLCD = 1.981
      KGALR = 5470.
      KVGLR = 2.649
      KAB = .0004445
      KVGLT = 14.15
      KSPEED = 138400.
      ICN=NRAT*16500.
      P3=P2
      P8=P0
      TV0 = T2
      RTH0 = SQRT(TV0/518.7)
      NC1 = ICN/RTH0
      NC1N = NC1/16500.
      BV8 = FUN2(1,NC1N,TV0,1)
      ABL=FUN1(1,BV8,1)
      IGVPR=FUN1(2,NC1N,2)
      BGVPR=FUN1(3,NC1N,3)
      TV(10) = T2
      III=0
      ITER1=0
      ITER2=0
      ITER3=0
      DO 60 K=1,NSSP
      FAB=FABGS
      T3=TBGS
      WIN=WINGS
      DWINX=.1
      PV(10) = P2*IGVPR - .005*P2
   39 CONTINUE
      WD(10)=WIN-FLOAT(K-1)*WDEL
      ITER1=ITER1+1
      KFIGV=KGALIG*(P2-PV(10))/(WD(10)*WD(10))
      WBL=0.
      WBLTBL=0.
      IF(SENSE SWITCH 3)8073,8074
 8074 CONTINUE
      IF(III.NE.1) GOTO 5901
 8073 CONTINUE
      J = 0
      WRITE(6,50) ICN,ABL,BV8,IGVPR,BGVPR
      WRITE(6,51)
      WRITE(6,52) J,PV(10),TV(10),WD(10)
 5901 CONTINUE
      DO 20 I=11,18
      J = I-10
      DELX = PV(I-1)/14.7
      RTHX = SQRT(TV(I-1)/518.7)
      NCX = ICN/RTHX
      WD(I)=WD(I-1)-WBL
      FPX=WD(I)*RTHX/(DELX*A(I))
      VZTX=KA(J)+FPX*(KA(J+10)+FPX*KA(J+20))
      KRAD(J) = K1*RAD(J)
      PHIX = VZTX/(KRAD(J)*NCX)
      GO TO (1,2,3,4,5,6,7,8),J
    1 CONTINUE
      PSIPX = FUN2(2,PHIX,BV8,3)
      PSITX=FUN2(5,PHIX,BV8,9)
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      GOTO 10
    2 CONTINUE
      PSIPX=FUN1(5,PHIX,6)
      PSITX=FUN1(6 ,PHIX,8 )
      GOTO 10
    3 CONTINUE
      PSIPX=FUN1(7,PHIX,10)
      PSITX=FUN1(8 ,PHIX,12)
      GOTO 10
    4 CONTINUE
      PSIPX=FUN1(9,PHIX,14)
      PSITX=FUN1(10,PHIX,16)
      GOTO 10
    5 CONTINUE
      PSIPX=FUN1(11,PHIX,18)
      PSITX=FUN1(12,PHIX,20)
      GOTO 10
    6 CONTINUE
      PSIPX=FUN1(13,PHIX,22)
      PSITX=FUN1(14,PHIX,24)
      GOTO 10
    7 CONTINUE
      PSIPX=FUN1(15,PHIX,26)
      PSITX=FUN1(16,PHIX,28)
      GOTO 10
    8 CONTINUE
      PSIPX=FUN1(17,PHIX,30)
      PSITX=FUN1(18,PHIX,32)
   10 CONTINUE
      KNR(J)=(ICN*RAD(J))**2/K2
      PV(I) = PV(I-1)*(1.+PSIPX*KNR(J)/TV(I-1))**3.5
      TV(I) = TV(I-1)+KNR(J)*PSITX
      TWV(I)=PV(I)/KVOL(J)
      WV(I)=TWV(I)/TV(I)
      PR = PV(I)/PV(I-1)
      WBL=KBLC(J)*ABL*PV(I)/SQRT(TV(I))
      IF(J.EQ.3) WBL3=WBL
      IF(J.EQ.4) WBL4=WBL
      IF(J.EQ.5) WBL5=WBL
      WBLTBL=WBLTBL+WBL*TV(I)
      IF(SENSE SWITCH 3)8075,8076
 8076 CONTINUE
      IF(III.NE.1) GOTO 5902
 8075 CONTINUE
      WRITE(6,52)J,PV(I),TV(I),WD(I),WBL,PSITX,VZTX,PHIX,PSIPX,PR
 5902 CONTINUE
   20 CONTINUE
      J = 18
      POGV = PV(18)*OGVPR
      TOGV = TV(18)
      WOGV=WD(18)
      KOGV = KGALOG*(PV(18)-POGV)/WOGV**2
      TWOG = POGV/KVOLOG
      WOOG = TWOG/TOGV
      PR23=POGV/P2
      TR23=TOGV/T2
      EFF23=(PR23**.285-1.)/(TR23-1.)
      IF(SENSE SWITCH 3)8077,8078
 8078 CONTINUE
      IF(III.NE.1) GOTO 5903
 8077 CONTINUE
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      WRITE(6,53)
      WRITE(6,52)J,PØGV,TØGV,WØGV,WBLTBL,EFF23,PR23,TR23
 5903 CØNTINUE
      J = 11
      PCD = PØGV
      TCD=TØGV
      CALL PRØCØM(0.,TCD,CPCD,GMCD,GMCDX,HCD,IFA)
      WCD =WØGV
      TWCD = FCL/KVØLCD
      WUCD = TWCD/TCD
      WTC=.033*WD(10)
      DLWHC=HCD*WCD*.24*(WBLTBL-WD(10)*TV(10))+SPLC
      KNAB =FUN1(21,ICN,38)*.975
      IF(SENSE SWITCH 3)8170,8171
 8171 CØNTINUE
      IF(III.NE.1) GØTØ 5904
 8170 CØNTINUE
      WRITE(6,54)
      WRITE(6,52)J,PCD,TCD,WCD,WTC,DLWHC,KNAB
 5904 CØNTINUE
      J=12
      KWB=FUN1(20,NRAT,36)
      WB=WCD-WTC
      IF(ITER1.EQ.1) PT=.35*PCD
      DPTX=1.
  220 CØNTINUE
      ITER2=ITER2+1
      DTBX=25.
      WTØLD=(1.+FAB)*WB
  221 NRTTB=ICN/SQRT(TB)
      ITER3=ITER3+1
      DELPB = KWB*WB**2/PCD*(.771*TCD-.085*TB)
      PB = PCD-DELPB
      PBDLTB = PB*(TB-TCD)
      ETAB =FUN1(19,PBDLTB,34)
      PTPB = PT/PB
      DHTNTB = FUN2(4,PTPB,NRTTB,7)
      DHT=DHTNTB*ICN/1000.*SQRT(TB)
  222 CALL PRØCØM(FAB,TB,CPB,GMB,GMBX,HB,IFA)
      IF(SENSE SWITCH 4)8098,8091
 8091 CØNTINUE
      WT1=WB*(18650.*ETAB-HCD)/(18650.*ETAB-HB)
      IF(IFA.GT.0) GØTØ 8071
      WTERR=ABS(WT1-WTØLD)
      IF(WTERR.GT..0005) GØTØ 223
 8072 CØNTINUE
      WF=WT1-WB
      FAB=WF/WB
      WN=WT1+WTC
      GØTØ 224
 8071 IF(WT1.LT.WB) WT1=WB
      IF(WT1.GT.(WB*1.067623)) WT1=1.067623*WB
      WTØLD=WT1
      GØTØ 8072
  223 WTØLD=(WT1+WTØLD)*.5
      WF=WTØLD-WB
      FAB=WF/WB
      GØTØ 222
  224 CØNTINUE
      HT=WT1/WN*(HB-DHT)+WTC/WN*HCD
      HBR=(DLWHC+WN*HT-HCD*WTC)/WT1
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      TBERR=HBR-HB
      IF(TBERR.GT..0005) GOTO 225
      IF(TBERR.LT.-.0005) GOTO 228
      GOTO 229
  225 IF(DTBX)226,226,227
  226 DTBX=-DTBX*.5
  227 TB=TB+DTBX
      GOTO 221
  228 IF(DTBX)227,227,226
  229 CONTINUE
      POPT=PO/PT
      IF(POPT-.528)233,233,230
  230 IF(POPT-1.)232,231,231
  231 WNTKNP=0.
      GOTO 234
  232 WNTKNP= POPT**(1./1.4)*SQRT(1.-POPT**(.4/1.4))
      GOTO 234
  233 WNTKNP=.2588
  234 CONTINUE
      WTTNPB=FUN2(3,PTPB,NRTTB,5)
      WT2=WTTNPB*PB/TB*ICN
      PTERR=WT2-WT1
  240 IF(PTERR.GT..0005) GOTO 241
      IF(PTERR.LT.-.0005) GOTO 245
      GOTO 250
  241 IF(DPTX)242,242,243
  242 DPTX=-DPTX*.5
  243 PT=PT+DPTX
      GOTO 220
  245 IF(DPTX)243,243,242
  250 CONTINUE
      FAT=WF/WN
      TT=TFNH(1,FAT,HT,TV)
      IF(SENSE SWITCH 4)8098,8092
 8092 CONTINUE
      WNX=(KNA8*PT*WNTKNP*A8)/SQRT(TT)
      WNERR=WNX-WN
      IF(III.EQ.1) GOTO 60
      IF(WNERR.GT..005) GOTO 5951
      IF(WNERR.LT.-.005) GOTO 5955
      III=1
      GOTO 99
 5951 IF(DWINX)5952,5952,5953
 5952 DWINX=-DWINX*.5
 5953 WIN=WIN+DWINX
      GOTO 99
 5955 IF(DWINX)5953,5953,5952
   60 CONTINUE
      DLWHT=HB*WT1+HCD*WTC-HT*WN
      WFM = 3600.*WF
      WRITE(6,56)
      WRITE(6,52) J,PB,TB,WB,ETAB,HB,PTPB,NRTTB,DHTNTB,WTTNPB
      J = 13
      WRITE(6,57)
      WRITE(6,52)J,PT,TT,WT1,WF,HT,DLWHT,WN,WNTKNP,A8
      WRITE(6,2108)ITER1,ITER2,ITER3
 2108 FORMAT(1H0,5X,8HITER1 = I5,5X,8HITER2 = I5,5X,8HITER3 = I5)
   50 FORMAT(1H1/4X,4HN = ,F8.2,4X,6HABL = ,F8.4,4X,6HBV0 = ,F8.4,4X,
     *8HIGVPR = ,F8.4,4X,8HOGVPR = ,F8.4)
   51 FORMAT(1H0,3X,1HJ,5X,5HPV(I),9X,5HTV(I),9X,5HWD(J),8X,6HWBL(J),8X
     *6HPSIT J,8X,6HVZT(J),8X,6HPHI(J),7X,7HPSIP(J),9X,5HPR(J))
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
   52 FORMAT(1H0,I4,9G14.5)
   53 FORMAT(1H0,3X,1HJ,6X,4HPOGV,10X,4HTOGV,10X,4HWOGV,8X,6HWBLTBL,9X,5
     1HEFF23,10X,4HPR23,10X,4HTR23)
   54 FORMAT(1H0,3X,1HJ,7X,3HPCD,11X,3HTCD,11X,3HWCD,11X,3HWTC,9X,5HDLWH
     1C,10X,4HKNAR)
   56 FORMAT(1H0,3X,1HJ,8X,2HPB,12X,2HTB,12X,2HWB,10X,4HETAB,12X,2HHB,
     110X,4HPTPB,9X,5HNRTTB,8X,6HDHTNTB,8X,6HWTTNPB)
   57 FORMAT(1H0,3X,1HJ,8X,2HPT,12X,2HTT,12X,2HWT,12X,2HWF,12X,2HHT,9X,5
     1HDLWHT,12X,2HWN,8X,6HWNTKNP,12X,2HAB)
      ICPVO = PV(10)
      ICWD0=WD(10)
      ICWD1=WD(11)
      ICWV1=WV(11)
      ICTWV1=TWV(11)
      ICWD2=WD(12)
      ICWV2=WV(12)
      ICTWV2=TWV(12)
      ICWD3=WD(13)
      ICWV3=WV(13)
      ICTWV3=TWV(13)
      ICWD4=WD(14)
      ICWV4=WV(14)
      ICTWV4=TWV(14)
      ICWD5=WD(15)
      ICWV5=WV(15)
      ICTWV5=TWV(15)
      ICWD6=WD(16)
      ICWV6=WV(16)
      ICTWV6=TWV(16)
      ICWD7=WD(17)
      ICWV7=WV(17)
      ICTWV7=TWV(17)
      ICWD8=WD(18)
      ICWV8=WV(18)
      ICTWV8=TWV(18)
      ICTWOG = TWOG
      ICWOGV = WOGV
      ICWDOG = WDOG
      ICTWCD = TWCD
      ICWCD = WCD
      ICWDCD = WDCD
      ICWB = WB
      ICPB = PB
      ICHB = HB
      ICRT =PT/K4/TT
      ICRHT = HT*ICRT
      ICTWVO = ICPVO/KVOLIG
      ICWVO = ICTWVO/TVO
      DO 298 I=1,8
      II=I+10
      KGAL(II)=KGAL(I)
  298 KVOL(II)=KVOL(I)
      READ(5,9011)(DX(I),I=1,NX)
 9011 FORMAT(8E10.4)
      IF(DX(1).NE.0.) GOTO 9701
      CCC=0.
      GOTO 9702
 9701 CONTINUE
      DO 9012 I=1,NX
 9012 DX(I)=2.*DX(I)
      CCC=.01*X(1)/DX(1)
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
 9702 CONTINUE
      DO 9013 I=1,NX
      DX(I)=DX(I)*CCC
 9013 X(I)=X(I)+DX(I)
      WRITE(3)(X(I),I=1,NX)
      READ(5,9014)DELT,FINTIME,PRDEL,OUTDEL
 9014 FORMAT(4G12.5)
      DT=DELT
      TIME=0.
      DTH=DELT*.5
      NXUE=NX+NU+NE
      SIGN=1.
      WRITE(9,8061)
      WRITE(9,8060)(X(I),I=1,NX)
 8060 FORMAT(E20.8)
 8061 FORMAT(1H1)
 3333 CONTINUE
      ISTEP=0
      NICOT=0
      CALL DYNAM(A,PV,TV,KGAL,KVOL,KNR,RAD,KRAD,KA,TAV,WD,HV,KBLD,DPRR)
      TIME=TIME+DELT
      IF(ABS(TIME-PRDEL).GT..000001) GOTO 3333
      PRDEL=PRDEL+OUTDEL
      WRITE(3)(X(I),I=1,NX)
      IF(ABS(TIME-FINTIME).GT..000001) GOTO 3333
 8098 CONTINUE
      PAUSE
      GOTO 8099
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      FUNCTION INTGRL(IC,DXDT)
      COMMON/TDATA/TIME,DT,ISTEP,NICOT
      DIMENSION G(40,4),XK(40)
      REAL IC,INTGRL
      IF(ISTEP.NE.0) GOTO 2
      IF(NICOT.NE.0) GOTO 1
      NI=39
    1 NICOT=NICOT+1
      G(NICOT,1)=DT*DXDT
      XK(NICOT)=IC
      INTGRL=XK(NICOT)+.5*G(NICOT,1)
      IF(NICOT.EQ.NI) ISTEP=1
      RETURN
    2 NICOT=NICOT+1
      GOTO(3,4,5),ISTEP
    3 G(NICOT,2)=DT*DXDT
      INTGRL=XK(NICOT)+.5*G(NICOT,2)
      IF(NICOT.EQ.NI) ISTEP=2
      RETURN
    4 G(NICOT,3)=DT*DXDT
      INTGRL=XK(NICOT)+G(NICOT,3)
      IF(NICOT.EQ.NI) ISTEP=3
      RETURN
    5 G(NICOT,4)=DT*DXDT
      INTGRL=XK(NICOT)+(G(NICOT,1)+2.*G(NICOT,2)+2.*G(NICOT,3)+G(NICOT,4
     1))/6.
      IF(NICOT.EQ.NI) ISTEP=4
      RETURN
      END
```

```
      FUNCTION TFNH(NX,FAX,HX,TV)
      DIMENSION TV(20)
      DTX=50.
      TX=TV(NX)
   51 CALL PROCOM(FAX,TX,CPX,GMX,GMXX,HX1,IFA)
      IF(IFA.GT.1) GOTO 70
      TXERR=HX-HX1
      IF(TXERR.GT..001) GOTO 52
      IF(TXERR.LT.-.001) GOTO 55
      GOTO 60
   52 IF(DTX)53,53,54
   53 DTX=-DTX*.5
   54 TX=TX+DTX
      GOTO 51
   55 IF(DTX)54,54,53
   60 CONTINUE
   70 CONTINUE
      TFNH=TX
      TV(NX)=TX
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      SUBROUTINE PROCOM(FARX,TEX,CP,GM,GMX,H,IFA)
      IFA=0
      IF(FARX.GT.0.) GOTO 2
      FARX=0.
      IFA=1
      GOTO 3
    2 IF(FARX.LT..067623) GOTO 3
      FARX=.067623
      IFA=1
    3 IF(TEX-1500.) 20,10,5
    5 IF(TEX.LT.4000.) GOTO 7
      TEX=4000.
      IF(IFA.EQ.1) GOTO 50
      IFA=2
      GOTO 16
   50 IFA=3
      GOTO 16
    7 IF(TEX-2300.) 9,14,8
    8 IF(TEX-2500.) 14,16,16
    9 IF(TEX-2000.) 10,12,12
   10 CPA = .2644+2.6E-5*(TEX-1500.)
      HA = (.22519+1.292E-5*TEX)*TEX+2.3733
      GO TO 40
   12 CPA = .27738+1.82E-5*(TEX-2000.)
      HA = (.22519+1.292E-5*TEX)*TEX+2.3733
      GO TO 40
   14 CPA = .27738+1.82E-5*(TEX-2000.)
      HA = (.25987+5.36E-6*TEX)*TEX-37.404
      GO TO 40
   16 CPA = .2865+1.17E-5*(TEX-2500.)
      HA = (.25987+5.36E-6*TEX)*TEX-37.404
      GO TO 40
   20 IF(TEX.GT.300.) GOTO 21
      TEX=300.
      IF(IFA.EQ.1) GOTO 51
      IFA=2
      GOTO 24
   51 IFA=3
      GOTO 24
   21 IF(TEX-900.) 23,28,22
   22 IF(TEX-1200.) 26,30,30
   23 IF(TEX-700.) 24,26,26
   24 CPA = .2392+1.1E-5*(TEX-500.)
      HA = (.22623+1.126E-5*TEX)*TEX+3.5214
      GO TO 40
   26 CPA = .2414+2.4E-5*(TEX-700.)
      HA = (.22623+1.126E-5*TEX)*TEX+3.5214
      GO TO 40
   28 CPA = .2458+3.1E-5*(TEX-900.)
      HA = (.22623+1.126E-5*TEX)*TEX+3.5214
      GO TO 40
   30 CPA = .2458+3.1E-5*(TEX-900.)
      HA = (.22519+1.292E-5*TEX)*TEX+2.3733
   40 CPF = .9333-(5.87E-5+3.27E-8*(3500.-TEX))*(3500.-TEX)
      HF = (.50699+6.180E-5*TEX)*TEX-132.20
      CP = (CPA+FARX*CPF)/(1.+FARX)
      H = (HA+FARX*HF)/(1.+FARX)
      AMW = 28.97-.946186*FARX
      REX = 1.98637/AMW
      GM = CP/(CP-REX)
      GMX = (GM-1.)/GM
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      SUBROUTINE DYNAM(A,PV,TV,KGAL,KVOL,KNR,RAD,KRAD,KA,THV,WD,WV,KBLD,
     1DPRB)
      DIMENSION A(20),PV(20),TV(20),KGAL(20),KVOL(20),KNR(8),RAD(8)
      DIMENSION KRAD(8),KA(30),THV(20),WD(20),WV(20),KBLD(3),DPRB(14)
      COMMON/TDATA/TIME,DT,ISTEP,NICNT
      COMMON/DATA/X(39),U(3),ETA(3),DXN(40),DX(40),DX1(40),CLM(40),
     1KVOLIG,KGALIG,KVOLBG,KGALBG,RTHO,ABL,KBGV,HTC,KVOLCD,KGALCD,TB,KHB
     2,KGALB,KVOLB,HT,TT,PT,K4,K2,WT,HCD,PO,WN,KNAB,KSPEED,KFIGV,K3,IGVP
     3R,TVO
      REAL ICTWVO,ICWVO
      REAL K5,K8,NC1,ICN,NC1N,IGVPR,IGV,K1,K3,K4,K6,K7,L,KGAL,KVOL
      REAL KVOLBG,KGALBG,KVOLCD,KGALCD,KGALB,KHB,KVOLB,KVOLT,KSPEED
      REAL KFIGV,NCX,KNR,KRAD,KA,KBGV,KNAB,NRTTB,ICPVO,ICWDO,ICWD1,ICWV1
      REAL ICTWV1,ICWD2,ICWV2,ICTWV2,ICWD3,ICWV3,ICTWV3,ICWD4,ICWV4
      REAL ICTWV4,ICWD5,ICWV5,ICTWV5,ICWD6,ICWV6,ICTWV6,ICWD7,ICWV7
      REAL ICTWV7,ICWD8,ICWV8,ICTWV8,ICTWBG,ICWBGV,ICWDBG,ICTWCD,ICWCD
      REAL ICWDCD,ICWB,ICPB,ICHB,ICRT,ICRHT,ICWFOP,NC2,NC3,NC4,NC5,NC6
      REAL NC7,NC8,NDEMO,ITER,IMPL,INTGRL,KIC
      REAL KAB,ICWDBG,N,NDT
      REAL KBLD,K2,NRAT,KGALIG,KVOLIG
      EQUIVALENCE (ICWDO,WDO,X(1 )),(ICWVO,WVO,X(2 )),(ICTWVO,TWVO,X(3 )
     1            ),(ICWD1,WD1,X(4 )),(ICWV1,WV1,X(5 )),(ICTWV1,TWV1,X(6 )
     2            ),(ICWD2,WD2,X(7 )),(ICWV2,WV2,X(8 )),(ICTWV2,TWV2,X(9 )
     3            ),(ICWD3,WD3,X(10)),(ICWV3,WV3,X(11)),(ICTWV3,TWV3,X(12)
     4            ),(ICWD4,WD4,X(13)),(ICWV4,WV4,X(14)),(ICTWV4,TWV4,X(15)
     5            ),(ICWD5,WD5,X(16)),(ICWV5,WV5,X(17)),(ICTWV5,TWV5,X(18)
     6            ),(ICWD6,WD6,X(19)),(ICWV6,WV6,X(20)),(ICTWV6,TWV6,X(21)
     7            ),(ICWD7,WD7,X(22)),(ICWV7,WV7,X(23)),(ICTWV7,TWV7,X(24)
     8            ),(ICWD8,WD8,X(25)),(ICWV8,WV8,X(26)),(ICTWV8,TWV8,X(27)
     9       ),(ICWDBG,WDBG,X(28)),(ICWBGV,WBGV,X(29)),(ICTWBG,TWBG,X(30))
     A      ,(ICWDCD,WDCD,X(31)),(ICWCD,WCD,X(32)),(ICTWCD,TWCD,X(33))
     B                           ,(ICWB,WB,X(34)),(ICPB,PB,X(35))
     C      ,(ICHB,HB,X(36)),(ICRHT,RHT,X(37)),(ICRT,RT,X(38))
     D      ,(ICN,N,X(39)),(WF,U(1)),(BVO,U(2)),(A8,U(3)),(P2,ETA(1))
     E      ,(T2,ETA(2)),(P8,ETA(3))
      EQUIVALENCE (WDODT   ,DX(1 )),(WVODT   ,DX(2 )),(TWVODT  ,DX(3 )),
     1            (WD1DT   ,DX(4 )),(WV1DT   ,DX(5 )),(TWV1DT  ,DX(6 )),
     2            (WD2DT   ,DX(7 )),(WV2DT   ,DX(8 )),(TWV2DT  ,DX(9 )),
     3            (WD3DT   ,DX(10)),(WV3DT   ,DX(11)),(TWV3DT  ,DX(12)),
     4            (WD4DT   ,DX(13)),(WV4DT   ,DX(14)),(TWV4DT  ,DX(15)),
     5            (WD5DT   ,DX(16)),(WV5DT   ,DX(17)),(TWV5DT  ,DX(18)),
     6            (WD6DT   ,DX(19)),(WV6DT   ,DX(20)),(TWV6DT  ,DX(21)),
     7            (WD7DT   ,DX(22)),(WV7DT   ,DX(23)),(TWV7DT  ,DX(24)),
     8            (WD8DT   ,DX(25)),(WV8DT   ,DX(26)),(TWV8DT  ,DX(27)),
     9            (WDBGDT  ,DX(28)),(WBGVDT  ,DX(29)),(TWBGDT  ,DX(30)),
     A            (WDCDDT  ,DX(31)),(WCDDT   ,DX(32)),(TWCDDT  ,DX(33)),
     B                              (WBDT    ,DX(34)),(PBDT    ,DX(35)),
     C            (HBDT    ,DX(36)),(RHTDT   ,DX(37)),(RTDT    ,DX(38)),
     D            (NDT     ,DX(39))
  999 CONTINUE
      TVO = TWVO/WVO
      RTHO=SQRT(TVO/518.7)
      ABL=FUN1(1,BVO,1)
      DO 299 I=1,8
  299 KNR(I)=(N*RAD(I))**2/K2
C
C DYNAMICS
C
C  INLET AND STAGE ONE
C
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      NC1 = N/RTH0
      NC1N = NC1/16500
      IGVPR=FUN1(1,NC1N,2)
      PD0 = P2-IGVPR*.005*P2
      TD0 = T2
      PV0 =KVOL(10)*TWV0
      WD0DT = KGAL(10)*(PD0-PV0)
      WV0DT = WD0 - WD1
      TWV0DT = 1.4*(TD0*WD0-TV0*WD1)
      PV1=KVOL(11)*TWV1
      DEL0 = PV0/14.7
      FP1 = WD1*RTH0/(DEL0*A(11))
      VZT1 = KA(1) + KA(11)*FP1 + KA(21)*FP1*FP1
      PHI1 = VZT1/(KRAD(1)*NC1)
      PSIP1 = FUN2(2,PHI1,BV0,4)
      PSIT1=FUN2(5,PHI1,BV0,10)
      PD1= PV0*(1.+PSIP1*KNR(1)/TV0)**3.5
      WD1DT=KGAL(11)*(PD1-PV1)
      WV1DT=WD1-WD2
      TV1 = TWV1/WV1
      TD1 = TV0+KNR(1)*PSIT1
      TWV1DT=1.4*(TD1*WD1-TV1*WD2)
C
C  STAGE TWO
C
      PV2 = KVOL(12)*TWV2
      RTH1 = SQRT(TV1/518.7)
      NC2 = N/RTH1
      DEL1 = PV1/14.7
      FP2 = WD2*RTH1/(DEL1*A(12))
      VZT2 = KA(2) + KA(12)*FP2 + KA(22)*FP2*FP2
      PHI2 = VZT2/(KRAD(2)*NC2)
      PSIP2=FUN1(5,PHI2,7)
      PD2 = PV1*(1.+PSIP2*KNR(2)/TV1)**3.5
      WD2DT=KGAL(12)*(PD2-PV2)
      WV2DT=WD2-WD3
      TV2 = TWV2/WV2
      PSIT2=FUN1(  ,PHI2,9 )
      TD2 = TV1+KNR(2)*PSIT2
      TWV2DT=1.4*(TD2*WD2-TV2*WD3)
C
C  STAGE THREE
C
      PV3 = KVOL(13)*TWV3
      RTH2 = SQRT(TV2/518.7)
      NC3 =N/RTH2
      DEL2 = PV2/14.7
      FP3 = WD3*RTH2/(DEL2*A(13))
      VZT3 = KA(3) + KA(13)*FP3 + KA(23)*FP3*FP3
      PHI3 = VZT3/(KRAD(3)*NC3)
      PSIP3=FUN1(7,PHI3,11)
      PD3 = PV2*(1.+PSIP3*KNR(3)/TV2)**3.5
      WD3DT=KGAL(13)*(PD3-PV3)
      TV3 = TWV3/WV3
      RTH3 = SQRT(TV3/518.7)
      WBL3 =KBLD(3)*ABL*PV3/(K3*RTH3)
      WV3DT=WD3-WD4-WBL3
      PSIT3=FUN1(  ,PHI3,13)
      TD3 = TV2+KNR(3)*PSIT3
      TWV3DT=1.4*(TD3*WD3-TV3*(WD4+WBL3))
C
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
C  STAGE FOUR
C
       PV4 = KVBL(14)*TWV4
       NC4 = N/RTH3
       DEL3 = PV3/14.7
       FP4 = WD4*RTH3/(DEL3*A(14))
       VZT4 = KA(4) + KA(14)*FP4 + KA(24)*FP4*FP4
       PHI4 = VZT4/(KRAD(4)*NC4)
       PSIP4=FUN1(9,PHI4,15)
       PD4 = PV3*(1.+PSIP4*KNR(4)/TV3)**3.5
       WD4DT=KGAL(14)*(PD4-PV4)
       TV4 = TWV4/WV4
       RTH4 = SQRT(TV4/518.7)
       WBL4 =KBLD(4)*ABL*PV4/(K3*RTH4)
       WV4DT=WD4-WD5-WBL4
       PSIT4=FUN1(10,PHI4,17)
       TD4 = TV3+KNR(4)*PSIT4
       TWV4DT=1.4*(TD4*WD4-TV4*(WD5+WBL4))
C
C  STAGE FIVE
C
       PV5 = KVBL(15)*TWV5
       NC5 = N/RTH4
       DEL4 = PV4/14.7
       FP5 = WD5*RTH4/(DEL4*A(15))
       VZT5 = KA(5) + KA(15)*FP5 + KA(25)*FP5*FP5
       PHI5 = VZT5/(KRAD(5)*NC5)
       PSIP5=FUN1(11,PHI5,19)
       PD5 = PV4*(1.+PSIP5*KNR(5)/TV4)**3.5
       WD5DT=KGAL(15)*(PD5-PV5)
       TV5 = TWV5/WV5
       RTH5 = SQRT(TV5/518.7)
       WBL5 =KBLD(5)*ABL*PV5/(K3*RTH5)
       WV5DT=WD5-WD6-WBL5
       PSIT5=FUN1(12,PHI5,21)
       TD5 = TV4+KNR(5)*PSIT5
       TWV5DT=1.4*(TD5*WD5-TV5*(WD6+WBL5))
C
C  STAGE SIX
C
       PV6 = KVBL(16)*TWV6
       NC6 = N/RTH5
       DEL5 = PV5/14.7
       FP6 = WD6*RTH5/(DEL5*A(16))
       VZT6 = KA(6) + KA(16)*FP6 + KA(26)*FP6*FP6
       PHI6 = VZT6/(KRAD(6)*NC6)
       PSIP6=FUN1(13,PHI6,23)
       PD6 = PV5*(1.+PSIP6*KNR(6)/TV5)**3.5
       WD6DT=KGAL(16)*(PD6-PV6)
       WV6DT=WD6-WD7
       TV6 = TWV6/WV6
       PSIT6=FUN1(14,PHI6,25)
       TD6 = TV5+KNR(6)*PSIT6
       TWV6DT=1.4*(TD6*WD6-TV6*WD7)
C
C  STAGE SEVEN
C
       PV7 = KVBL(17)*TWV7
       RTH6 = SQRT(TV6/518.7)
       NC7 = N/RTH6
       DEL6 = PV6/14.7
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      FP7 = WD7*RTH6/(DEL6*A(17))
      VZT7 = KA(7) + KA(17)*FP7 + KA(27)*FP7*FP7
      PHI7 = VZT7/(KRAD(7)*NC7)
      PSIP7=FUN1(15,PHI7,27)
      PD7 = PV6*(1.+PSIP7*KNR(7)/TV6)**3.5
      WD7DT=KGAL(17)*(PD7-PV7)
      WV7DT=WD7-WD8
      TV7 = TWV7/WV7
      PSIT7=FUN1(16,PHI7,29)
      TD7 = TV6+KNR(7)*PSIT7
      TWV7DT=1.4*(TD7*WD7-TV7*WD8)
C
C  STAGE EIGHT
C
      PV8 = KVOL(18)*TWV8
      RTH7 = SQRT(TV7/518.7)
      NC8 = N/RTH7
      DEL7 = PV7/14.7
      FP8 = WD8*RTH7/(DEL7*A(18))
      VZT8 = KA(8) + KA(18)*FP8 + KA(28)*FP8*FP8
      PHI8 = VZT8/(KRAD(8)*NC8)
      PSIP8=FUN1(17,PHI8,31)
      PD8 = PV7*(1.+PSIP8*KNR(8)/TV7)**3.5
      WD8DT=KGAL(18)*(PD8-PV8)
      WV8DT=WD8-WOGV
      TV8 = TWV8/WV8
      PSIT8=FUN1(18,PHI8,33)
      TD8    [illegible]7+KNR(8)*PSIT8
      TW[illegible] 1.4*(TD8*WD8-TV8*WOGV)
C
C  OUTLET GUIDE VANES
C
      TOGV = TWOG/WDOG
      TWOGDT=1.4*(TV8*WOGV-TOGV*WCD)
      POGV = KVOLOG*TWOC
      WOGVDT=KGALOG*(PV8-POGV)-KOGV*WOGV*WOGV
      WDOGDT=WOGV-WCD
C
C  COMPRESSOR DISCHARGE
C
      WTC = [illegible]033*[illegible]
      TCD = TWCD/WDCD
      TWCDDT=(TOGV*WCD-TCD*(WB+WTC))*1.4
      PCD = KVOLCD*TWCD
      WCDDT=KGALCD*(POGV-PCD)
      WDCDDT=WCD-WB-WTC
C
C  BURNER
C
      FAB=WF/WB
      TB=TFNH(2,FA[illegible],HB,TV)
      DELPB = KWB*W[illegible]**2/PCD*(.771*TCD-.085*TB)
      WBDT = KGALB*(PCD-PB-DELPB)
      NRTTB = N/SQRT(TB)
      HT = RHT/WT
      FAT=WF/(WB+WF+WTC)
      TT=TFNH(3,FAT,HT,TV)
      PT = K4*RT*TT
      PTPB = PT/PB
      WTTNPB = FUN2(3,PTPB,NRTTB,6)
      WT = WTTNPB*[illegible]*PB/TB
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      PBDLTB=PB*(TB-TCD)
      ETAB=FUN1(19,PBDLTB,35)
      CALL PROCOM(0.,TCD,CPCD,GMCD,GMCDX,HCD,IFA)
      PBDT=KVBLB*(HCD*WB+18650.*ETAB*WF-WT*HB)
      WBDT = HB/PB*(PBDT-KVBLB/1.4*HB*(WB+WF-WT))
      POPT=P6/PT
      WNTKNP=HBKEY(POPT)
      WN = WNTKNP*A8*KNA8*PT/SQRT(TT)
      DHTNTB = FUN2(4,PTPB,NRTTB,8)
      DHT=N/1000.*DHTNTB*SQRT(TB)
      RHTDT=(HB*WT+HCD*WTC-DHT*WT- T*WN)/1.53
      RTDT = (WT+WTC-WN)/1.53
      WBLTBL = WBL3*TV3+WBL4*TV4+WBL5*TV5
      DLWHC=HCD*WCD+.24*(WBLTBL-TV0*WD0)
      DLWHT=HB*WT+HCD*WTC-HT*WN
      NDT=KSPEED/N*(DLWHT-DLWHC)
      WD0 = INTGRL(ICWD0,WD0DT)
      WV0 = INTGRL(ICWV0,WV0DT)
      TWV0=INTGRL(ICTWV0,TWV0DT)
      WD1=INTGRL(ICWD1,WD1DT)
      WV1=INTGRL(ICWV1,WV1DT)
      TWV1=INTGRL(ICTWV1,TWV1DT)
      WD2=INTGRL(ICWD2,WD2DT)
      WV2=INTGRL(ICWV2,WV2DT)
      TWV2=INTGRL(ICTWV2,TWV2DT)
      WD3=INTGRL(ICWD3,WD3DT)
      WV3=INTGRL(ICWV3,WV3DT)
      TWV3=INTGRL(ICTWV3,TWV3DT)
      WD4=INTGRL(ICWD4,WD4DT)
      WV4=INTGRL(ICWV4,WV4DT)
      TWV4=INTGRL(ICTWV4,TWV4DT)
      WD5=INTGRL(ICWD5,WD5DT)
      WV5=INTGRL(ICWV5,WV5DT)
      TWV5=INTGRL(ICTWV5,TWV5DT)
      WD6=INTGRL(ICWD6,WD6DT)
      WV6=INTGRL(ICWV6,WV6DT)
      TWV6=INTGRL(ICTWV6,TWV6DT)
      WD7=INTGRL(ICWD7,WD7DT)
      WV7=INTGRL(ICWV7,WV7DT)
      TWV7=INTGRL(ICTWV7,TWV7DT)
      WD8=INTGRL(ICWD8,WD8DT)
      WV8=INTGRL(ICWV8,WV8DT)
      TWV8=INTGRL(ICTWV8,TWV8DT)
      TWBG=INTGRL(ICTWBG,TWBGDT)
      WBGV=INTGRL(ICWBGV,WBGVDT)
      WDBG=INTGRL(ICWDBG,WDBGDT)
      TWCD=INTGRL(ICTWCD,TWCDDT)
      WCD=INTGRL(ICWCD,WCDDT)
      WDCD=INTGRL(ICWDCD,WDCDDT)
      WB = INTGRL(ICWB,WBDT)
      PB = INTGRL(ICPB,PBDT)
      HB = INTGRL(ICHB,HBDT)
      RHT = INTGRL(ICRHT,RHTDT)
      RT = INTGRL(ICRT,RTDT)
      N = INTGRL(ICN,NDT)
      NICNT=0
      GOTO(999,999,999,998),ISTOP
  998 CONTINUE
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      FUNCTION HOKEY(POPT)
      IF(POPT.GE.1.) GOTO 1
      IF(POPT.GE..53) HOKEY=POPT**(1./1.4)*SQRT(1.-POPT**(.4/1.4))
      IF(POPT.GE.0..AND.POPT.LE..53) HOKEY=.2588
      RETURN
    1 HOKEY=0.
      RETURN
      END
```

```
      FUNCTION FN1SET(N,ZX,NP,N1,N2)
      COMMON XX(17,5),YY(17,5),NX(5),NY(5),[illegible](17,17,5),YDEL(40),
     1II(40),JJ(40),SLP1(40),SLP2(40),ZPT1(40),ZPT2(40)
      COMMON        X1(21,21),Z1(21,21),KK(50),MX(23),XDIF(50),SLP(50),
     1ZPT(50)
      DIMENSION ZX(1)
      MX(N) = NP
      DO 10 J=1,NP
      K=2*J
      X1(J,N) = ZX(K-1)
   10 Z1(J,N) = ZX(K)
      FN1SET = 1.
      DO 30 NR=N1,N2
      KK(NR) = 2
      XDIF(NR) = X1(2,N)-X1(1,N)
      ZPT(NR) = Z1(1,N)
      SLP(NR) =(Z1(2,N)-Z1(1,N))/XDIF(NR)
   30 CONTINUE
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      FUNCTION FUN1(N,XIN,NR)
      COMMON XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(17,17,5),YDEL(40),
     1II(40),JJ(40),SLP1(40),SLP2(40),ZPT1(40),ZPT2(40)
      COMMON        X1(21,21),Z1(21,21),KK(50),MX(23),XDIF(50),SLP(50),
     1ZPT(50)
C
      IOLD = KK(NR)
      NXP = MX(N)
      IF(XIN-X1(IOLD,N)) 105,105,120
  105 IF(XIN-X1(IOLD-1,N)) 140,140,110
  110 I = IOLD
      GO TO 250
C     COUNT UP
  120 IF(XIN-X1(NXP,N)) 125,180,300
  125 NF = IOLD + 1
      DO 130 I = NF,NXP
      IF(XIN-X1(I,N)) 200,200,130
  130 CONTINUE
      GO TO 200
C     COUNT DOWN
  140 IF(XIN-X1(1,N)) 300, 190,145
  145 NL = IOLD - 2
      DO 150 K = 1,NL
      I = IOLD - K
      IF(XIN-X1(I-1,N)) 150,150, 200
  150 CONTINUE
      GO TO 200
  180 I = NXP
      GO TO 200
  190 I = 2
  200 XDIF(NR) = X1(I,N)-X1(I-1,N)
      ZPT(NR) = Z1(I-1,N)
      SLP(NR) =(Z1(I,N)-ZPT(NR))/XDIF(NR)
  250 XINC = XIN-X1(I-1,N)
      FUN1 = ZPT(NR)+XINC*SLP(NR)
      KK(NR) = I
      RETURN
  300 CONTINUE
      IF(XIN.LT.X1(1,N))FUN1=Z1(1,N)
      IF(XIN.GT.X1(NXP,N))FUN1=Z1(NXP,N)
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Continued)

```
      FUNCTION FN2SET(N,X,Y,Z,NXP,NYP,N1,N2)
      COMMON XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(17,17,5),YDEL(40),
     1II(40),JJ(40),SLP1(40),SLP2(40),ZPT1(40),ZPT2(40)
      COMMON         X1(21,21),Z1(21,21),KK(50),MX(23),XDIF(50),SLP(50),
     1ZPT(50)
      DIMENSION X( 1),Y(1),Z(1)
   10 NX(N) = NXP
      NY(N) = NYP
      DO 15 J=1,NYP
      YY(J,N) = Y(J)
      DO 15 I=1,NXP
      K = I+(J-1)*NXP
   15 ZZZ(I,J,N) = Z(K)
      DO 20 I=1,NXP
   20 XX(I,N) = X(I)
      FN2SET = 1.0
      DO 30 NR=N1,N2
      II(NR) = 2
      JJ(NR) = 2
      XDEL = XX(2,N)-XX(1,N)
      YDEL(NR) = YY(2,N)-YY(1,N)
      ZPT1(NR) = ZZZ(1,1,N)
      ZPT2(NR) = ZZZ(1,2,N)
      SLP1(NR) = (ZZZ(2,1,N)-ZPT1(NR))/XDEL
      SLP2(NR) = (ZZZ(2,2,N)-ZPT2(NR))/XDEL
   30 CONTINUE
      RETURN
      END
```

Table A-1. Nonlinear Engine Simulation Program (Concluded)

```
      FUNCTION FUN2(N,XIN,YIN,NR)
      COMMON XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(17,17,5),YDEL(40),
     1II(40),JJ(40),SLP1(40),SLP2(40),ZPT1(40),ZPT2(40)
      COMMON        X1(21,21),Z1(21,21),KK(50),MX(23),XDIF(50),SLP(50),
     1ZPT(50)
C     TEST FOR X IN PREVIOUS INTERVAL
      NXP = NX(N)
      IOLD = II(NR)
      IF(XIN - XX(IOLD,N)) 105,105,120
  105 IF(XIN - XX(IOLD-1,N)) 140,140,110
  110 I = IOLD
      GO TO 200
C     COUNT UP
  120 IF(XIN - XX(NXP,N))  125,180,180
  125 NF = IOLD + 1
      DO 130 I = NF,NXP
      IF(XIN - XX(I,N))200,200,130
  130 CONTINUE
      GO TO 200
C     COUNT DOWN
  140 IF(XIN-XX(1,N)) 190,190,145
  145 NL = IOLD -2
      DO 150K = 1,NL
      I = IOLD - K
      IF(XIN-XX(I-1,N))150,150,200
  150 CONTINUE
      GOTO 200
  180 I=NXP
      XIN=XX(NXP,N)
      GO TO 200
  190 I = 2
      XIN=XX(1,N)
C     TEST FOR Y IN PREVIOUS INTERVAL
  200 NYP = NY(N)
      JOLD = JJ(NR)
      IF(YIN - YY(JOLD,N)) 205, 205, 220
  205 IF(YIN - YY(JOLD-1,N)) 240,240,210
  210 J = JOLD
      IF(I-IOLD) 300,400,300
C     COUNT UP
  220 IF(YIN - YY(NYP,N)) 225, 280,280
  225 NF = JOLD + 1
      DO 230 J = NF,NYP
      IF(YIN - YY(J,N)) 300,300,230
  230 CONTINUE
      GO TO 300
C     COUNT DOWN
  240 IF(YIN - YY(1,N))290,290,245
  245 NL = JOLD - 2
      DO 250 K = 1,NL
      J = JOLD - K
      IF(YIN -YY(J-1,N)) 250,250,300
  250 CONTINUE
      GO TO 300
  280 J = NYP
      YIN=YY(NYP,N)
      GO TO 300
  290 J = 2
      YIN=YY(1,N)
C     COMPUTE Z(Y) INTERCEPTS AND SLOPES
  300 XDEL = XX(I,N)-XX(I-1,N)
      YDEL(NR) = YY(J,N)-YY(J-1,N)
      ZPT1(NR) = ZZZ(I-1,J-1,N)
      ZPT2(NR) = ZZZ(I-1,J,N)
      SLP1(NR) = (ZZZ(I,J-1,N)-ZPT1(NR))/XDEL
      SLP2(NR) = (ZZZ(I,J,N)-ZPT2(NR))/XDEL
C     INTERPOLATE FOR ANSWER
  400 II(NR) = I
      JJ(NR) = J
      XINC = XIN-XX(I-1,N)
      P1ZZ = ZPT1(NR)+XINC*SLP1(NR)
      P2ZZ = ZPT2(NR)+XINC*SLP2(NR)
      YFRAC = (YIN-YY(J-1,N))/YDEL(NR)
      FUN2 = P1ZZ + YFRAC*(P2ZZ-P1ZZ)
      RETURN
      END
```

Table A-2. Reduced-Order Component Model

```
      DIMENSION IGV(42),A(20),PV(20),TV(20),YY1(14),XX1(17),ZZ1(196)
      DIMENSION L(20),V(20),KGAL(20),KVOL(20),KNR(8),RAD(8),KRAD(8)
      DIMENSION KA(30)
      DIMENSION TWV(20),WD(20),WV(20),KBLD(8),DPRB(14)
      COMMON/TDATA/TIME,DTH
      COMMON/DATA/X( 2),U(4),ETA(3),DXN( 6),DX( 6),DX1( 6),CLM( 6),KVOLI
     1G,     RTHO,     KVOLOG,KGALOG,KOGV,WTC,KVOLCD,KGALCD,    KWB,KGALB,
     2HT,      K4,K2,WT,HCD,KVOLB,PO,WN,KNAB,KSPEED,KGALIG,KFIGV,K3,
     3WBL3,WBL4,WBL5,WCD,WDCD,TWCD,ETAB,DHT
     4,TCD,     WB,HB,PB,ERROR
      REAL K5,K8,NC1,ICN,NC1N,IGVPR,IGV,K1,K3,K4,K6,K7,L,KGAL,KVOL
      REAL KVOLOG,KGALOG,KVOLCD,KGALCD,KGALB,KWB,KVOLB,KVOLT,KSPEED
      REAL KFIGV,NCX,KNR,KRAD,KA,KOGV,KNAB,NRTTB,ICPVO,ICWDO,ICWD1,ICWV1
      REAL ICTWV1,ICWD2,ICWV2,ICTWV2,ICWD3,ICWV3,ICTWV3,ICWD4,ICWV4
      REAL ICTWV4,ICWD5,ICWV5,ICTWV5,ICWD6,ICWV6,ICTWV6,ICWD7,ICWV7
      REAL ICTWV7,ICWD8,ICWV8,ICTWV8,ICTWOG,ICWOGV,ICWDOG,ICTWCD,ICWCD
      REAL ICWDCD,ICWS,ICPB,ICHB,ICRT,ICRHT,ICWFOP,NC2,NC3,NC4,NC5,NC6
      REAL NC7,NC8,NDEMD,ITER,IMPL,INTGRL,KIC
      REAL KAB,ICWDOG,N,NDT
      REAL KBLD,K2,NRAT,KGALIG,KVOLIG
      EQUIVALENCE(ICN,N,X(1))
      EQUIVALENCE
     2              (NDT,DX( 1)),(WF,U(1)),(BVB,U(2)),(A8,U(3)),(P2,ETA(1
     3)),(TVO,T2,ETA(2)),(P8,ETA(3)),(U(4),ABL)
      EQUIVALENCE (TMIC,TM,X(2)),(TMDT,DX(2))
      EQUIVALENCE (PCD,DX(3)),(PT,DX(4)),(TB,DX(5)),(TT,DX(6))
      REWIND 3
 8099 CONTINUE
      READ(5,6306) ERROR
      IF(ERROR.EQ.0.0) GO TO 8098
 6306 FORMAT(G12.5)
      READ(5,8030) NX,NU,NE,NR,DPERT
 8030 FORMAT(4I2,G12.5)
      REWIND 7
      DATA (DPRB(I),I=1,14)/.60,7.26E-4,.70,7.07E-4,.80,6.98E-4,.85,6.9E
     1-4,.90,6.96E-4,.97,6.96E-4,1.0,7.38E-4/
      DATA (KBLD(I),I=1,8)/2*0.,1.1025,1.0572,1.0411,3*0./
      DATA (KGAL(I),I=1,8)/25542.,27942.,27247.,26407.,24084.,21872.,221
     156.,22439./
      DATA (KVOL(I),I=1,8)/1.9107,3.3711,4.9797,7.0830,9.3087,11.2953,13
     1.7727,15.1219/
      DATA (TV(I),I=1,20)/5*1600.,15*518.7/
      DATA (TWV(I),I=1,20)/20*10./
      DATA (WD(I),I=1,20)/20*30./
      DATA (WV(I),I=1,20)/20*.01/
      READ(7)(IGV(I),I=1,18)
      F11 =FN1SET(1,IGV   ,9,1,1)
      READ(7)(IGV(I),I=1,38)
      F14 =FN1SET(4,IGV ,19,4,5)
      READ(7)(IGV(I),I=1,20)
      F12 =FN1SET(2,IGV,10,2,2)
      READ(7)(IGV(I),I=1,18)
      F13 =FN1SET(3,IGV,9, 3,3)
      READ(7)(IGV(I),I=1,40)
      F15 =FN1SET(5,IGV  ,20,6,7)
      READ(7)(IGV(I),I=1,42)
      F16 =FN1SET(6,IGV ,21,8,9)
      READ(7)(IGV(I),I=1,34)
      F17 =FN1SET(7,IGV  ,17,10,11)
      READ(7)(IGV(I),I=1,38)
```

Table A-2. Reduced-Order Component Model (Continued)

```
            F18 =FN1SET(8,IGV ,19,12,13)
            READ(7)(IGV(I),I=1,36)
            F19 =FN1SET(9,IGV  ,18,14,15)
            READ(7)(IGV(I),I=1,40)
            F110=FN1SET(10,IGV,20,16,17)
            READ(7)(IGV(I),I=1,32)
            F111=FN1SET(11,IGV  ,16,18,19)
            READ(7)(IGV(I),I=1,36)
            F112=FN1SET(12,IGV,18,20,21)
            READ(7)(IGV(I),I=1,26)
            F113=FN1SET(13,IGV  ,13,22,23)
            READ(7)(IGV(I),I=1,26)
            F114=FN1SET(14,IGV ,13,24,25)
            READ(7)(IGV(I),I=1,30)
            F115=FN1SET(15,IGV  ,15,26,27)
            READ(7)(IGV(I),I=1,26)
            F116=FN1SET(16,IGV,13,28,29)
            READ(7)(IGV(I),I=1,30)
            F117=FN1SET(17,IGV  ,15,30,31)
            READ(7)(IGV(I),I=1,32)
            F118=FN1SET(18,IGV ,16,32,33)
            READ(7)(IGV(I),I=1,28)
            F119=FN1SET(19,IGV ,14,34,35)
            F120=FN1SET(20,DPRB,7,36,37)
            READ(7)(IGV(I),I=1,40)
            IGV(6)=1.39
            IGV(8)=1.395
            DO 6301 I=9,39,2
            II=I+1
            XSQ=IGV(I)*IGV(I)
            FBFX=XSQ*1.031964679E-8-IGV(I)*1.735930756E-4+2.129761925
      6301  IGV(II)=FBFX
            F121=FN1SET(21,IGV   ,20,38,39)
             READ(7)(A(I),I=1,20)
             READ(7)(L(I),I=1,20)
             READ(7)(V(I),I=1,20)
             READ(7)(IGV (I),I=1,20)
             READ(7)(IGV (I),I=1,20)
             READ(7)(RAD(I),I=1,8)
             READ(7)(KRAD(I),I=1,8)
             READ(7)(PV(I),I=1,20)
             READ(7)(IGV(I),I=1,20)
             READ(7)(YY1(I),I=1,5)
             READ(7)(XX1(I),I=1,13)
             READ(7)(ZZ1(I),I=1,65)
            F1= FN2SET(1,XX1,YY1,ZZ1,13,5,1,2)
             READ(7)(KA(I),I=1,30)
             READ(7)(YY1(I),I=1,4)
             READ(7)(XX1(I),I=1,17)
             READ(7)(ZZ1(I),I=1,68)
            F2 = FN2SET(2,XX1,YY1,ZZ1,17,4,3,4)
             READ(7)(YY1(I),I=1,14)
             READ(7)(XX1(I),I=1,14)
             READ(7)(ZZ1(I),I=1,196)
            F3 = FN2SET(3,XX1,YY1,ZZ1,14,14,5,6)
             READ(7)(YY1(I),I=1,14)
             READ(7)(XX1(I),I=1,14)
             READ(7)(ZZ1(I),I=1,196)
            F4 = FN2SET(4,XX1,YY1,ZZ1,14,14,7,8)
            READ(7)     (YY1(I),I=1,4)
            READ(7)     (XX1(I),I=1,17)
```

Table A-2. Reduced-Order Component Model (Continued)

```
      READ(7)     (ZZ1(I),I=1,68)
      F5=FN2SET(5,XX1,YY1,ZZ1,17,4,9,10)
C
C SET PAFAMETERS
C
      KAB=0
      NSSP=1
      TTGS=1700.
      READ(5,8066)NRAT,WINGS,SPLC,BV0,ABL
      WRITE(9,8066) ERRBR
      WRITE(9,8030) NX,NU,NE,NR,DPERT
      WRITE(9,8066)NRAT,WINGS,SPLC,BV0,ABL
      READ(5,9903) P2,T2
 9903 FBRMAT(2G12.5)
      WRITE(9,9903) P2,T2
 8066 FBRMAT(6G12.5)
      A8=A8FN(NRAT)
      AJ=A8
      TBGS=2100.
      FABGS=.02
      T2=518.7
      WDEL=.1
      DTH=DELT*.5
      TIME=0.
      K1 = 3.14159/360.
      K2=7.*32.17*53.35/(K1*K1)
      K3=SQRT(518.7)
      K4=(53.35*12.)/17600.
      KGALIG=51837.
      KVPLIG=3.31
      KGALAG = 22430.
      KVPLAG = 15.10
      KGALCD = 8730.
      KVPLCD = 1.981
      KGALB=54.7
      KVBLB = 2.659
      KWB = .0004445
      KVBLT = 14.15
      KSPEED = 138400.
      ICN=NRAT*16500.
      P3=P2
      P8=P3
      TV0 = T2
      RTH0 = SQRT(TV0/518.7)
      NC1 = ICN/RTH0
      NC1N = NC1/16500.
      BV0B=FUN2(1,NC1N,TV0,1)
      ABLB=FUN1(1,BV0B,1)
      IGVPR=FUN1(2,NC1N,2)
      BGVPR=FUN1(3,NC1N,3)
      TV(10) = T2
      III=0
      ITER1=0
      ITER2=0
      ITER3=0
      DB 60 K=1,NSSP
      FAB=FABGS
      TB=TBGS
      WIN=WINGS
      DWINX=.01
      PV(10) = P2*IGVPR - .005*P2
```

Table A-2. Reduced-Order Component Model (Continued)

```
   99 CØNTINUE
      WD(10)=WIN-FLØAT(K-1)*WDEL
      ITER1=ITER1+1
      KFIGV=KGALIG*(P2-PV(10))/(WD(10)*WD(10))
      WBL=0.
      WBLTØL=0.
      IF(SENSE SWITCH 3)8073,8074
 8074 CØNTINUE
      IF(III.NE.1) GØTØ 5901
 8073 CØNTINUE
      J = 0
      WRITE(6,50) ICN,ABL,BVB,IGVPR,RGVPR
      WRITE(6,51)
      WRITE(6,52) J,PV(10),TV(10),WD(10)
 5901 CØNTINUE
      DØ 20 I=11,18
      J = I-10
      DELX = PV(I-1)/14.7
      RTHX = SQRT(TV(I-1)/518.7)
      NCX = ICN/RTHX
      WD(I)=WD(I-1)-WBL
      FPX=WD(I)*RTHX/(DELX*A(I))
      VZTX=KA(J)+FPX*(KA(J+10)+FPX*KA(J+20))
      KRAD(J) = K1*RAD(J)
      PHIX = VZTX/(KRAD(J)*NCX)
      GØ TØ (1,2,3,4,5,6,7,8),J
    1 CØNTINUE
      PSIPX = FUN2(2,PHIX,BVB,3)
      PSITX=FUN2(5,PHIX,BVB,9)
      GØTØ 10
    2 CØNTINUE
      PSIPX=FUN1(5,PHIX,6)
      PSITX=FUN1(4 ,PHIX,8 )
      GØTØ 10
    3 CØNTINUE
      PSIPX=FUN1(7,PHIX,10)
      PSITX=FUN1(8 ,PHIX,12)
      GØTØ 10
    4 CØNTINUE
      PSIPX=FUN1(9,PHIX,14)
      PSITX=FUN1(10,PHIX,16)
      GØTØ 10
    5 CØNTINUE
      PSIPX=FUN1(11,PHIX,18)
      PSITX=FUN1(12,PHIX,20)
      GØTØ 10
    6 CØNTINUE
      PSIPX=FUN1(13,PHIX,22)
      PSITX=FUN1(14,PHIX,24)
      GØTØ 10
    7 CØNTINUE
      PSIPX=FUN1(15,PHIX,26)
      PSITX=FUN1(16,PHIX,28)
      GØTØ 10
    8 CØNTINUE
      PSIPX=FUN1(17,PHIX,30)
      PSITX=FUN1(18,PHIX,32)
   10 CØNTINUE
      KNR(J)=(ICN*RAD(J))**2/K2
      PV(I) = PV(I-1)*(1.+PSIPX*KNR(J)/TV(I-1))**3.5
      TV(I) = TV(I-1)+KNR(J)*PSITX
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000363          TWV(I)=PV(I)/KVOL(J)
00000364          WV(I)=TWV(I)/TV(I)
00000365          PR = PV(I)/PV(I-1)
00000366          WBL=KBLD(J)*ABL*PV(I)/SQRT(TV(I))
00000367          IF(J.EQ.3) WBL3=WBL
00000370          IF(J.EQ.4) WBL4=WBL
00000371          IF(J.EQ.5) WBL5=WBL
00000372          WBLTBL=WBLTBL+WBL*TV(I)
00000373          IF(SENSE SWITCH 3)8075,8076
00000374     8076 CONTINUE
00000375          IF(III.NE.1) GOTO 5902
00000376     8075 CONTINUE
00000377          WRITE(9,52)J,PV(I),TV(I),WD(I),WBL,PSITX,V7TX,PHIX,PSIPX,PR
00000400     5902 CONTINUE
00000401       20 CONTINUE
00000402          J = 10
00000403          POGV = PV(18)*OGVPR
00000404          TOGV = TV(18)
00000405          WOGV=WD(18)
00000406          KOGV = KGALOG*(PV(18)-POGV)/WOGV**2
00000407          TWOG = POGV/KVOLOG
00000410          WDOG = TWOG/TOGV
00000411          PR23=POGV/P2
00000412          TR23=TOGV/T2
00000413          EFF23=(PR23**.285-1.)/(TR23-1.)
00000414          IF(SENSE SWITCH 3)8077,8078
00000415     8078 CONTINUE
00000416          IF(III.NE.1) GOTO 5903
00000417     8077 CONTINUE
00000420          WRITE(6,53)
00000421          WRITE(6,52)J,POGV,TOGV,WOGV,WBLTBL,EFF23,PR23,TR23
00000422     5903 CONTINUE
00000423          J = 11
00000424          PCD = POGV
00000425          TCD=TOGV
00000426          CALL PROCOM(0.,TCD,CPCD,GMCD,GMCDX,HCD,IFA)
00000427          WCD =WOGV
00000430          TWCD = PCD/KVOLCD
00000431          WDCD = TWCD/TCD
00000432          WTC=.033*WD(10)
00000433          DLWHC=HCD*WCD+.24*(WBLTBL-WD(10)*TV(10))+SPLC
00000434          KNA8=5.0405-.0429772*A8+.000126664*A8**2
00000435          IF(SENSE SWITCH 3)8170,8171
00000436     8171 CONTINUE
00000437          IF(III.NE.1) GOTO 5904
00000440     8170 CONTINUE
00000441          WRITE(6,54)
00000442          WRITE(6,52)J,PCD,TCD,WCD,WTC,DLWHC,KNA8
00000443     5904 CONTINUE
00000444          J=12
00000445          KWB=FUN1(20,NRAT,36)
00000446          WB=WCD-WTC
00000447          IF(ITER1.EQ.1) PT=.35*PCD
00000450          DPTX=1.
00000451      220 CONTINUE
00000452          ITER2=ITER2+1
00000453          DTBX=25.
00000454          WTOLD=(1.+FAB)*WB
00000455      221 NRTTB=ICN/SQRT(TB)
00000456          ITER3=ITER3+1
00000457          DELPB = KWB*WB**2/PCD*(.771*TCD-.085*TB)
```

Table A-2. Reduced-Order Component Model (Continued)

```
      PB = PCD-DELPB
      PBDLTB = PB*(TB-TCD)
      ETAB =FUN1(19,PBDLTB,34)
      PTPB = PT/PB
      DHTNTB = FUN2(4,PTPB,NRTTB,7)
      DHT=DHTNTB*ICN/1000.*SQRT(TB)
  222 CALL PROCOM(FAB,TB,CPB,GMB,GMBX,HB,IFA)
      IF(SENSE SWITCH 4)8098,8091
 8091 CONTINUE
      WT1=WB*(18650.*ETAB-HCD)/(18650.*ETAB-HB)
      IF(IFA.GT.0) GOTO 8071
      WTERR=ABS(WT1-WTOLD)
      IF(WTERR.GT..0005) GOTO 223
 8072 CONTINUE
      WF=WT1-WB
      FAB=WF/WB
      WN=WT1+WTC
      GOTO 224
 8071 IF(WT1.LT.WB) WT1=WB
      IF(WT1.GT.(WB*1.067623)) WT1=1.067623*WB
      WTOLD=WT1
      GOTO 8072
  223 WTOLD=(WT1+WTOLD)*.5
      WF=WTOLD-WB
      FAB=WF/WB
      GOTO 222
  224 CONTINUE
      HT=WT1/WN*(HB-DHT)+WTC/WN*HCD
      HBR=(DLWHC+WN*HT-HCD*WTC)/WT1
      TBERR=HBR-HB
      IF(TBERR.GT..0005) GOTO 225
      IF(TBERR.LT.-.0005) GOTO 228
      GOTO 229
  225 IF(DTBX)226,226,227
  226 DTBX=-DTBX*.5
  227 TB=TB+DTBX
      GOTO 221
  228 IF(DTBX)227,227,226
  229 CONTINUE
      POPT=PO/PT
      IF(POPT-.528)233,233,230
  230 IF(POPT-1.)232,231,231
  231 WNTKNP=0.
      GOTO 234
  232 WNTKNP= POPT**(1./1.4)*SQRT(1.-POPT**(.4/1.4))
      GOTO 234
  233 WNTKNP=.2588
  234 CONTINUE
      WTTNPB=FUN2(3,PTPB,NRTTB,5)
      WT2=WTTNPB*PB/TB*ICN
      PTERR=WT2-WT1
  240 IF(PTERR.GT..0005) GOTO 241
      IF(PTERR.LT.-.0005) GOTO 245
      GOTO 250
  241 IF(DPTX)242,242,243
  242 DPTX=-DPTX*.5
  243 PT=PT+DPTX
      GOTO 220
  245 IF(DPTX)243,243,242
  250 CONTINUE
      FAT=WF/WN
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000555          TT=TFNH(1,FAT,WT,TV)
00000556          IF(SENSE SWITCH 4)8098,8092
00000557   8092   CONTINUE
00000560          WNX=(KNA8*PT*WNTKNP*A8)/SQRT(TT)
00000561          WNERR=WNX-WN
00000562          IF(III.EQ.1) GOTO 60
00000563          IF(WNERR.GT..005) GOTO 5951
00000564          IF(WNERR.LT.-.005) GOTO 5955
00000565          III=1
00000566          GOTO 99
00000567   5951   IF(DWINX)5952,5952,5953
00000570   5952   DWINX=-DWINX*.5
00000571   5953   WIN=WIN+DWINX
00000572          GOTO 99
00000573   5955   IF(DWINX)5953,5953,5952
00000574     60   CONTINUE
00000575          DLWHT=HB*WT1+HCD*WTC-HT*WN
00000576          WFM = 3600.*WF
00000577          WRITE(6,56)
00000600          WRITE(6,52) J,PB,TB,WB,ETAB,HB,PTPB,WRTTB,DHTNTB,WTTNPB
00000601          J = 13
00000602          WRITE(6,57)
00000603          WRITE(6,52)J,PT,TT,WT1,WF,HT,DLWHT,WN,WNTKNP,A8
00000604          ACD=50.7334498
00000605          CFMCD=WCD*SQRT(53.3*TCD/(1.4*32.2))/(PCD*ACD)
00000606          FMCD=RNFM(CFMCD)
00000607          CFMN=WN*SQRT(53.3*TT/(1.4*32.2))/(PT*AJ)
00000610          FMN=RNFM(CFMN)
00000611          FMNS=FMN*FMN
00000612          AAA=1.+.2*FMNS
00000613          AAA=AAA**3.5
00000614          AAA=1./AAA
00000615          AAA=(1.4*FMNS+1.)*AAA
00000616          THRUST=(PT*AAA-P2)*AJ
00000617          SPFC=WFM/THRUST
00000620          WRITE(9,6791)FMCD,FMN,WFM,THRUST,SPFC
00000621   6791   FORMAT(1H0,2X,5H MCD=G13.5,4H MN=G13.5,5H WFM=G13.5,8H THRUST=G13.
00000622         15,6H SPFC=G13.5)
00000623          PCDP2=PCD/P2
00000624          WRITE(9,6792)PCDP2
00000625   6792   FORMAT(1H0,7H P3/P2=G13.5)
00000626          WRITE(6,2108)ITER1,ITER2,ITER3
00000627   2108   FORMAT(1H0,5X,8HITER1 = I5,5X,8HITER2 = I5,5X,8HITER3 = I5)
00000630     50   FORMAT(1H1/4X,4HN = ,F8.2,4X,6HABL = ,F8.4,4X,6HBVO = ,F8.4,4X,
00000631         *8HIGVPR = ,F8.4,4X,8HOGVPR = ,F8.4)
00000632     52   FORMAT(1H0,I3,9G13.5)
00000633     51   FORMAT(1H0,2X,1HJ,4X,5HPV(J),8X,5HTV(J),8X,5HWD(J),7X,6HWBL(J),7X,
00000634         18HPSITX(J),6X,7HVZTX(J),6X,7HPHIX(J),6X,8HPSIPX(J),5X,5HPR(J))
00000635     53   FORMAT(1H0,3X,1HJ,6X,4HPOGV,10X,4HTOGV,10X,4HWOGV,8X,6HWBLTBL,9X,5
00000636         1HEFF23,10X,4HPR23,10X,4HTR23)
00000637     54   FORMAT(1H0,3X,1HJ,7X,3HPCD,11X,3HTCD,11X,3HWCD,11X,3HWTC,9X,5HDLWH
00000640         1T,10X,4HKNA8)
00000641     56   FORMAT(1H0,3X,1HJ,8X,2HPB,12X,2HTB,12X,2HWB,10X,4HETAB,12X,2HHB,
00000642         110X,4HPTPB,9X,5HWRTTB,8X,6HDHTNTB,8X,6HWTTNPB)
00000643     57   FORMAT(1H0,3X,1HJ,8X,2HPT,12X,2HTT,12X,2HWT,12X,2HWF,12X,2HHT,9X,5
00000644         1HDLWHT,12X,2HWN,8X,6HWNTKNP,12X,2HA8)
00000645          ICPV0 = PV(10)
00000646          ICWD0=WD(10)
00000647          ICWD1=WD(11)
00000650          ICWV1=WV(11)
00000651          ICTWV1=TWV(11)
```

Table A-2. Reduced-Order Component Model (Continued)

```
      ICWD2=WD(12)
      ICWV2=WV(12)
      ICTWV2=TWV(12)
      ICWD3=WD(13)
      ICWV3=WV(13)
      ICTWV3=TWV(13)
      ICWD4=WD(14)
      ICWV4=WV(14)
      ICTWV4=TWV(14)
      ICWD5=WD(15)
      ICWV5=WV(15)
      ICTWV5=TWV(15)
      ICWD6=WD(16)
      ICWV6=WV(16)
      ICTWV6=TWV(16)
      ICWD7=WD(17)
      ICWV7=WV(17)
      ICTWV7=TWV(17)
      ICWD8=WD(18)
      ICWV8=WV(18)
      ICTWV8=TWV(18)
      ICTWBG = TWBG
      ICWBGV = WBGV
      ICWDBG = WDBG
      ICTWCD = TWCD
      ICWCD = WCD
      ICWDCD = WDCD
      ICWB = WB
      ICPB  = PB
      ICHB = HB
      ICRT =PT/K4/TT
      ICRHT = HT*ICRT
      DO 298 I=1,8
      II=I+10
      KGAL(II)=KGAL(I)
  298 KVBL(II)=KVBL(I)
      TMIC=TB
      TBSS=TB
      TM=TB
 3333 CONTINUE
      NXUE=NX+NU+NE
      NX1=NX+1
      NXR=NX+NR
      SIGN=1.
      WRITE(9,8061)
      WRITE(9,8060)(X(I),I=1,NX)
 8060 FORMAT(E20.8)
 8061 FORMAT(1H1)
      WT=WT1
      CALL DYNAM(A,PV,TV,KGAL,KVBL,KNR,RAD,KRAD,KA,TWV,WD,WV,KBLD,DPRB,1
     1)
      WBL   =WBL3
      WBL-  =WBL4
      WBL5S=WBL5
      WTS=WT
      WTCS=WTC
      WRITE(9,8061)
      WRITE(9,9000)
 9000 FORMAT(////,5X,41HSTEADY STATE DATA FROM SUBROUTINE DYNAMIC,///)
      WRITE(9,9001)
 9001 FORMAT(8X,1HN,14X,2HWF,13X,2HAB,13X,3HBVB,12X,3HABL)
```

Table A-2. Reduced-Order Component Model (Continued)

```
      WRITE(9,9010) N,WF,AB,BV3,ABL
      WRITE(9,9002)
 9002 FORMAT(//,6X,4HWBL3,11X,4HWBL4,11X,4HWBL5)
      WRITE(9,9010) WBL3,WBL4,WBL5
      WRITE(9,9003)
 9003 FORMAT(//,7X,3HWCD,12X,3HTCD,12X,3HPCD,12X,3HHCD)
      WRITE(9,9010) WCD,TCD,PCD,HCD
      WRITE(9,9004)
 9004 FORMAT(//,7X,2HWB,13X,2HTB,13X,2HPB,13X,2HHB,13X,3HKWB,11X,4HETAB)
      WRITE(9,9010) WB,TB,PB,HB,KWB,ETAB
      WRITE(9,9005)
 9005 FORMAT(//,7X,2HWT,13X,2HTT,13X,2HPT,13X,2HHT)
      WRITE(9,9010) WT,TT,PT,HT
      WRITE(9,9006)
 9006 FORMAT(//,7X,2HWN,12X,4HKNAB,12X,3HNDT,11X,4HTMDT,12X,2HTM)
      WRITE(9,9010) WN,KNAB,NDT,TMDT,TM
 9010 FORMAT(2X,E12.5,7(3X,E12.5))
      WRITE(9,8061)
      WRITE(9,8060)(DX(I),I=1,NX)
      WRITE(9,8061)
      WRITE(9,8060) (DX(I),I=NX1,NXR)
      DO 8031 I=1,NXR
 8031 DXN(I)=DX(I)
C ONE
C TWO
      DO 8040 J=1,NXE
 8032 SIGN=-1.*SIGN
      IF(X(J).NE..0) GOTO 3703
      IF(SIGN.LT..0) GOTO 8032
      PERT=DPERT
      GOTO 3704
 3703 CONTINUE
      PERT=SIGN*X(J)*DPERT
 3704 CONTINUE
      X(J)=X(J)+PERT
      CALL DYNAM(A,PV,TV,KJAL,KVBL,KKR,RAD,KRAD,KA,TWV,WD,WV,KBLD,DPRB,2
     1)
      WBL3=WBL3S
      WBL4=WBL4S
      WBL5=WBL5S
      WT=WTS
      WTC=WTCS
      X(J)=X(J)-PERT
      IF(X(J).EQ..0) GOTO 3705
      IF(SIGN)8033,8034,8035
 8033 CONTINUE
      IF(SIGN.LT..0.AND.ABS(X(J)-1.0).LT.ABS(PERT)) GO TO 3701
      DO 8034 I=1,NXR
      DX1(I)=DX(I)
C THREE
C FOUR
 8034 DX(I)=DXN(I)
      GO TO 8032
 3701 CONTINUE
      SIGN=-1.0*SIGN
      DO 3707 I=1,NXR
      DX1(I)=DX(I)
 3707 X(I)=DXN(I)
      PERT=[illegible]PERT
      GOTO 3705
 3705 CONTINUE
```

Table A-2. Reduced-Order Component Model (Continued)

```
00001044        DO 3702 I=1,NXR
00001045   3702 DX1(I)=DXN(I)
00001046        PERT=.5*PERT
00001047  C FIVE
00001050  C SIX
00001051        GOTO 8035
00001052   8035 CONTINUE
00001053   3074 FORMAT(1H1/7X,8H COLUMN I3/)
00001054        DO 8036 I=1,NXR
00001055        CLM(I)=(DX(I)-DX1(I))/(2.*ABS(PERT))
00001056   3076 FORMAT(I3,4E20.10)
00001057   8036 DX(I)=DXN(I)
00001060        WRITE(3) (CLM(I),I=1,NX)
00001061        WRITE(3) (CLM(I),I=NX1,NXR)
00001062   8040 CONTINUE
00001063        GOTO 8099
00001064   8098 CONTINUE
00001065        PAUSE
00001066        GOTO 8099
00001067        END
```

```
00000000        FUNCTION   INTGRL(IC,DXDT)
00000001        COMMON/TDATA/TIME,DTH
00000002        DIMENSION DN1(50)
00000003        REAL IC,INTGRL
00000004        INTGRL=IC
00000005        RETURN
00000006        END
```

```
00000000        FUNCTION IDX(I,J,N,NX,NY)
00000001        DIMENSION NX(5),NY(5)
00000002        KSUM=0
00000003        IF(N.EQ.1) GOTO 1
00000004        NN=N-1
00000005        DO 2 L=1,NN
00000006      2 KSUM=KSUM+NX(L)*NY(L)
00000007      1 CONTINUE
00000010        IDX=KSUM+I+(J-1)*NX(N)
00000011        RETURN
00000012        END
```

```
00000000        FUNCTION ABFN(NRAT)
00000001        REAL NRAT
00000002        IF(NRAT.GT..85) GOTO 1
00000003        ABFN=162.01
00000004        RETURN
00000005      1 A=70.51/.15+91.5
00000006        B=-70.51/.15
00000007        ABFN=A+B*NRAT
00000010        RETURN
00000011        END
```

Table A-2. Reduced-Order Component Model (Continued)

```
      FUNCTION FN1SET(N,ZX,NP,N1,N2)
      COMMON XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(593),YDEL(10),II(10),JJ(1
     10),SLP1(10),SLP2(10),ZPT1(10),ZPT2(10)
      COMMON X1(21,21),Z1(21,21),KK(40),MX(23),XDIF(40),SLP(40),ZPT(40)
      DIMENSION ZX(1)
      MX(N) = NP
      DO 10 J=1,NP
      K=2*J
      X1(J,N) = ZX(K-1)
   10 Z1(J,N) = ZX(K)
      FN1SET = 1.0
      DO 30 NR=N1,N2
      KK(NR) = 2
      XDIF(NR) = X1(2,N)-X1(1,N)
      ZPT(NR) = Z1(1,N)
      SLP(NR) =(Z1(2,N)-Z1(1,N))/XDIF(NR)
   30 CONTINUE
      RETURN
      END
```

```
      FUNCTION FN2SET(N,X,Y,Z,NXP,NYP,N1,N2)
      COMMON XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(593),YDEL(10),II(10),JJ(1
     10),SLP1(10),SLP2(10),ZPT1(10),ZPT2(10)
      COMMON X1(21,21),Z1(21,21),KK(40),MX(23),XDIF(40),SLP(40),ZPT(40)
      DIMENSION X( 1),Y(1),Z(1)
   10 NX(N) = NXP
      NY(N) = NYP
      DO 15 J=1,NYP
      YY(J,N) = Y(J)
      DO 15 I=1,NXP
      K = I+(J-1)*NXP
      LL=IDX(I,J,N,NX,NY)
   15 ZZZ(LL)=Z(K)
      DO 20 I=1,NXP
   20 XX(I,N) = X(I)
      FN2SET = 1.0
      DO 30 NR=N1,N2
      II(NR) = 2
      JJ(NR) = 2
      XDEL = XX(2,N)-XX(1,N)
      YDEL(NR) = YY(2,N)-YY(1,N)
      LL=IDX(1,1,N,NX,NY)
      ZPT1(NR)=ZZZ(LL)
      LL=IDX(1,2,N,NX,NY)
      ZPT2(NR)=ZZZ(LL)
      LL=IDX(2,1,N,NX,NY)
      SLP1(NR)=(ZZZ(LL)-ZPT1(NR))/XDEL
      LL=IDX(2,2,N,NX,NY)
      SLP2(NR)=(ZZZ(LL)-ZPT2(NR))/XDEL
   30 CONTINUE
      RETURN
      END
```

Table A-2. Reduced-Order Component Model (Continued)

```
      FUNCTIØN RNFM(C)
      XK=C
      IF(C.LT..58) GØTØ 1
      RNFM=1.
      RETURN
    1 XKS=XK*XK
      A=(1.+.2*XKS)
      AS=A*A
      AC=AS*A
      UP=C*AC-XK
      DN=1.2*C*XK*AS-1.
      XKP1=XK-(UP/DN)
      RAT=ABS(XKP1/XK)
      RAT=ABS(RAT-1.)
      IF(RAT.GT..001) GØTØ 10
      RNFM=XKP1
      RETURN
   10 XK=XKP1
      GØTØ 1
      END
```

```
      FUNCTIØN TFNH(NX,FAX,HX,TV)
      DIMENSIØN TV(20)
      DTX=50.
      TX=TV(NX)
   51 CALL PRØCØM(FAX,TX,CPX,GMX,GMXX,HX1,IFA)
      IF(IFA.GT.1) GØTØ 70
      TXERR=HX-HX1
      IF(TXERR.GT..001) GØTØ 52
      IF(TXERR.LT.-.001) GØTØ 55
      GØTØ 60
   52 IF(DTX)53,53,54
   53 DTX=-DTX*.5
   54 TX=TX+DTX
      GØTØ 51
   55 IF(DTX)54,54,53
   60 CØNTINUE
   70 CØNTINUE
      TFNH=TX
      TV(NX)=TX
      RETURN
      END
```

Table A-2. Reduced-Order Component Model (Continued)

```
      SUBROUTINE PRPCOM(FARX,TEX,CP,GM,GMX,H,IFA)
      IFA=0
      IF(FARX.GT.0.) GOTO 2
      FARX=0.
      IFA=1
      GOTO 3
    2 IF(FARX.LT..067623) GOTO 3
      FARX=.067623
      IFA=1
    3 IF(TEX-1500.) 20,10,5
    5 IF(TEX.LT.4000.) GOTO 7
      TEX=4000.
      IF(IFA.EQ.1) GOTO 50
      IFA=2
      GOTO 10
   50 IFA=3
      GOTO 10
    7 IF(TEX-2300.) 9,14,8
    8 IF(TEX-2500.) 14,16,16
    9 IF(TEX-2000.) 10,12,12
   10 CPA = .2644+2.6E-5*(TEX-1500.)
      HA = (.22519+1.292E-5*TEX)*TEX+2.3733
      GO TO 40
   12 CPA = .27738+1.82E-5*(TEX-2000.)
      HA = (.22519+1.292E-5*TEX)*TEX+2.3733
      GO TO 40
   14 CPA = .27738+1.82E-5*(TEX-2000.)
      HA = (.25987+5.36E-6*TEX)*TEX-17.404
      GO TO 40
   16 CPA = .2865+1.17E-5*(TEX-2500.)
      HA = (.25987+5.36E-6*TEX)*TEX-17.404
      GO TO 40
   20 IF(TEX.GT.300.) GOTO 21
      TEX=300.
      IF(IFA.EQ.1) GOTO 51
      IFA=2
      GOTO 24
   51 IFA=4
      GOTO 24
   21 IF(TEX-900.) 23,28,22
   22 IF(TEX-1200.) 28,30,30
   23 IF(TEX-700.) 24,26,26
   24 CPA = .2392+1.1E-5*(TEX-500.)
      HA = (.22623+1.126E-5*TEX)*TEX+3.5214
      GO TO 40
   26 CPA = .2414+2.4E-5*(TEX-700.)
      HA = (.22623+1.126E-5*TEX)*TEX+3.5214
      GO TO 40
   28 CPA = .2458+3.1E-5*(TEX-900.)
      HA = (.22623+1.126E-5*TEX)*TEX+3.5214
      GO TO 40
   30 CPA = .2458+3.1E-5*(TEX-900.)
      HA = (.22579+1.292E-5*TEX)*TEX+2.3733
   40 CPF = .9333-(5.87E-5+3.27E-8*(3500.-TEX))*(3500.-TEX)
      HF = (.50899+6.180E-5*TEX)*TEX-132.20
      CP = (CPA+FARX*CPF)/(1.+FARX)
      H = (HA+FARX*HF)/(1.+FARX)
      AMW = 28.97-.946186*FARX
      REX = 1.98637/AMW
      GM = CP/(CP-REX)
      GMX = (GM-1.)/GM
      RETURN
      END
```

Table A-2. Reduced-Order Component Model (Continued)

```
      FUNCTIØN FUN1(N,XIN,NR)
      CØMMØN XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(593),YDEL(10),II(10),JJ(1
     10),SLP1(10),SLP2(10),ZPT1(10),ZPT2(10)
      CØMMØN X1(21,21),Z1(21,21),KK(40),MX(23),XDIF(40),SLP(40),ZPT(40)
C
      IØLD = KK(NR)
      NXP = MX(N)
      IF(XIN-X1(IØLD,N)) 105,105,120
  105 IF(XIN-X1(IØLD-1,N)) 140,140,110
  110 I = IØLD
      GØ TØ 250
C     CØUNT UP
  120 IF(XIN-X1(NXP,N)) 125,180,300
  125 NF = IØLD + 1
      DØ 130 I = NF,NXP
      IF(XIN-X1(I,N)) 200,200,130
  130 CØNTINUE
      GØ TØ 200
C     CØUNT DØWN
  140 IF(XIN-X1(1,N)) 300, 190,145
  145 NL = IØLD - 2
      DØ 150 K = 1,NL
      I = IØLD - K
      IF(XIN-X1(I-1,N)) 150,150, 200
  150 CØNTINUE
      GØ TØ 200
  180 I = NXP
      GØ TØ 200
  190 I = 2
  200 XDIF(NR) = X1(I,N)-X1(I-1,N)
      ZPT(NR) = Z1(I-1,N)
      SLP(NR) =(Z1(I,N)-ZPT(NR))/XDIF(NR)
  250 XINC = XIN-X1(I-1,N)
      FUN1 = ZPT(NR)+XINC*SLP(NR)
      KK(NR) = I
      RETURN
  300 CØNTINUE
      IF(XIN.LT.X1(1,N))FUN1=Z1(1,N)
      IF(XIN.GT.X1(NXP,N))FUN1=Z1(NXP,N)
      RETURN
      END
```

Table A-2. Reduced-Order Component Model (Continued)

```
      FUNCTION FUN2(N,XIN,YIN,NR)
      COMMON XX(17,5),YY(17,5),NX(5),NY(5),ZZZ(593),YDEL(10),II(10),JJ(1
     10),SLP1(10),SLP2(10),ZPT1(10),ZPT2(10)
      COMMON X1(21,21),Z1(21,21),KK(40),MX(23),XDIF(40),SLP(40),ZPT(40)
C     TEST FOR X IN PREVIOUS INTERVAL
      XP = NX(N)
      IOLD = II(NR)
      IF(XIN - XX(IOLD,N)) 105,105,120
  105 IF(XIN - XX(IOLD-1,N)) 140,140,110
  110 I = IOLD
      GO TO 200
C     COUNT UP
  120 IF(XIN - XX(NXP,N))  125,180,180
  125 NF = IOLD + 1
      DO 130 I = NF,NXP
      IF(XIN - XX(I,N))200,200,130
  130 CONTINUE
      GO TO 200
C     COUNT DOWN
  140 IF(XIN-XX(1,N)) 190,190,145
  145 NL = IOLD -2
      DO 150K = 1,NL
      I = IOLD - K
      IF(XIN-XX(I-1,N))150,150,200
  150 CONTINUE
      GOTO 200
  180 I=NXP
      XIN=XX(NXP,N)
      GO TO 200
  190 I = 2
      XIN=XX(1,N)
C     TEST FOR Y IN PREVIOUS INTERVAL
  200 NYP = NY(N)
      JOLD = JJ(NR)
      IF(YIN - YY(JOLD,N)) 205, 205, 220
  205 IF(YIN - YY(JOLD-1,N)) 240,240,210
  210 J = JOLD
      IF(I-IOLD) 300,400,300
C     COUNT UP
  220 IF(YIN - YY(NYP,N)) 225, 280,280
  225 NF = JOLD + 1
      DO 230 J = NF,NYP
      IF(YIN - YY(J,N)) 300,300,230
  230 CONTINUE
      GO TO 300
C     COUNT DOWN
  240 IF(YIN - YY(1,N))290, 290,245
  245 NL = JOLD - 2
      DO 250 K = 1,NL
      J = JOLD - K
      IF(YIN -YY(J-1,N)) 250,250,300
  250 CONTINUE
      GO TO 300
  280 J = NYP
      YIN=YY(NYP,N)
      GO TO 300
  290 J = 2
      YIN=YY(1,N)
C     COMPUTE Z(Y) INTERCEPTS AND SLOPES
  300 XDEL = XX(I,N)-XX(I-1,N)
```

Table A-2. Reduced-Order Component Model (Continued)

```
00000074          YDEL(NR) = YY(J,N)-YY(J-1,N)
00000075          LL=IDX(I-1,J-1,N,NX,NY)
00000076          ZPT1(NR)=ZZZ(LL)
00000077          LL=IDX(I-1,J,N,NX,NY)
00000100          ZPT2(NR)=ZZZ(LL)
00000101          LL=IDX(I,J-1,N,NX,NY)
00000102          SLP1(NR)=(ZZZ(LL)-ZPT1(NR))/XDEL
00000103          LL=IDX(I,J,N,NX,NY)
00000104          SLP2(NR)=(ZZZ(LL)-ZPT2(NR))/XDEL
00000105    C     INTERPOLATE FOR ANSWER
00000106      400 II(NR) = I
00000107          JJ(NR) = J
00000110          XINC = XIN-XX(I-1,N)
00000111          P1ZZ = ZPT1(NR)+XINC*SLP1(NR)
00000112          P2ZZ = ZPT2(NR)+XINC*SLP2(NR)
00000113          YFRAC = (YIN-YY(J-1,N))/YDEL(NR)
00000114          FUN2 = P1ZZ + YFRAC*(P2ZZ-P1ZZ)
00000115          RETURN
00000116          END
```

Table A-2. Reduced-Order Component Model (Continued)

```
      SUBROUTINE DYNAM(A,PV,TV,KGAL,KVBL,KNR,RAD,KRAD,KA,TAV,WD,WV,KBLD,
     1DPRB,INIT)
      DIMENSION A(20),PV(20),TV(20),KGAL(20),KVBL(20),KNR(8),RAD(8)
      DIMENSION KRAD(8),KA(30),TAV(20),WD(20),WV(20),KBLD(8),DPRB(14)
      COMMON/TDATA/TIME,DTH
      COMMON/DATA/X( 2),U(4),ETA(3),DXN( 6),DX( 6),DX1( 6),CLM( 6),KVBLI
     1G,      RTHB,     KVBLBG,KGALBG,KBGV,WTC,KVBLCD,KGALCD,    KAB,KGALB,
     2HT,       K4,K2,WT,HCD,KVBLB,PO,WN,KNAB,KSPEED,KGALIG,KFIGV,K3,
     3WBL3,WBL4,WBL5,WCD,WDCD,TWCD,ETAB,DHT
     4,TCD,     WB,HB,PB,ERROR
      REAL K5,K8,NC1,ICN,NC1N,IGVPR,IGV,K1,K3,K4,K6,K7,L,KGAL,KVBL
      REAL KVBLBG,KGALBG,KVBLCD,KGALCD,KGALB,KAB,KVBLB,KVBLT,KSPEED
      REAL KFIGV,NCX,KNR,KRAD,KA,KBGV,KNAB,NRTTB,ICPVO,ICWDO,ICWD1
      REAL            ICWD2,                 ICWD3,                 ICWD4
      REAL            ICWD5,                 ICWD6,                 ICWD7
      REAL            ICWD8,                          ICWDBG,ICTWCD,ICWCD
      REAL ICWDCD,ICWB,ICPB,ICHB,ICRT,ICRHT,ICWFWP,NC2,NC3,NC4,NC5,NC6
      REAL NC7,NC8,NDEND,ITER,IMPL,INTGRL,KIC
      REAL KAB,ICWDBG,NWDT
      REAL KBLD,K2,NRAT,KGALIG,KVBLIG
      EQUIVALENCE(ICN,NX(1))
      EQUIVALENCE
     2               (NDT,DX( 1)),(WF,U(1)),(BVB,U(2)),(AB,U(3)),(P2,ETA(1
     3)),(TV2,T2,ETA(2)),(PB,ETA(3)),(U(4),ABL)
      EQUIVALENCE (TWIC,TM,X(2)),(TMDT,DX(2))
      EQUIVALENCE (PCD,DX(3)),(PT,DX(4)),(TB,DX(5)),(TT,DX(6))
      WB=WT-WF
      WDC=WB+WTC+WBL3+WBL4+WBL5
   98 CONTINUE
      DELPT=0.1
      DELWDO=0.01
      ITER1=0
      ITER2=0
   99 CONTINUE
      RTHO=SQRT(TV0/518.7)
      DO 299 I=1,8
  299 KNR(I)=(N*RAD(I))**2/K2
C
C DYNAMICS
C
C  INLET AND STAGE ONE
C
      NC1 = N/RTHO
      NC1N = NC1/16500
      IGVPR = FUN1(2,NC1N,2)
      PV0 = P2*IGVPR + .005*P2
      WD1 = WD0
      DELO = PV0/14.7
      FP1 = WD1*RTHO/(DELO*A(1))
      VZT1 = KA(1) + KA(11)*FP1 + KA(21)*FP1*FP1
      PHI1 = VZT1/(KRAD(1)*NC1)
      PSIP1 = FUN2(2,PHI1,BVB,4)
      PD1= PV0*(1.+PSIP1*KNR(1)/TV0)**3.5
      PV1 = PD1
      PSIT1=FUN2(5,PHI1,BVB,10)
      TD1 = TV0+KNR(1)*PSIT1
      TV1 = TD1
C
C  STAGE TWO
C
```

Table A-2. Reduced-Order Component Model (Continued)

```
      RTH1 = SQRT(TV1/518.7)
      NC2 = N/RTH1
      DEL1 = PV1/14.7
      WD2 = WD1
      FP2 = WD2*RTH1/(DEL1*A(12))
      VZT2 = KA(2) + KA(12)*FP2 + KA(22)*FP2*FP2
      PHI2 = VZT2/(KRAD(2)*NC2)
      PSIP2=FUN1(5,PHI2,7)
      PD2 = PV1*(1.+PSIP2*KNR(2)/TV1)**3.5
      PV2 = PD2
      PSIT2=FUN1(6 ,PHI2,9 )
      TD2 = TV1+KNR(2)*PSIT2
      TV2 = TD2
C
C  STAGE THREE
C
      RTH2 = SQRT(TV2/518.7)
      NC3 =N/RTH2
      DEL2 = PV2/14.7
      WD3 = WD2
      FP3 = WD3*RTH2/(DEL2*A(13))
      VZT3 = KA(3) + KA(13)*FP3 + KA(23)*FP3*FP3
      PHI3 = VZT3/(KRAD(3)*NC3)
      PSIP3=FUN1(7,PHI3,11)
      PD3 = PV2*(1.+PSIP3*KNR(3)/TV2)**3.5
      PV3 = PD3
      PSIT3=FUN1(8 ,PHI3,13)
      TD3 = TV2+KNR(3)*PSIT3
      TV3 = TD3
      RTH3 = SQRT(TV3/518.7)
      WBL3 =KBLD(3)*ABL*PV3/(K3*RTH3)
C
C  STAGE FOUR
C
      WD4 = WD3-WBL3
      NC4 = N/RTH3
      DEL3 = PV3/14.7
      FP4 = WD4*RTH3/(DEL3*A(14))
      VZT4 = KA(4) + KA(14)*FP4 + KA(24)*FP4*FP4
      PHI4 = VZT4/(KRAD(4)*NC4)
      PSIP4=FUN1(9 ,PHI4,15)
      PD4 = PV3*(1.+PSIP4*KNR(4)/TV3)**3.5
      PV4 = PD4
      PSIT4=FUN1(10,PHI4,17)
      TD4 = TV3+KNR(4)*PSIT4
      TV4 = TD4
      RTH4 = SQRT(TV4/518.7)
      WBL4 =KBLD(4)*ABL*PV4/(K3*RTH4)
C
C  STAGE FIVE
C
      WD5 = WD4-WBL4
      NC5 = N/RTH4
      DEL4 = PV4/14.7
      FP5 = WD5*RTH4/(DEL4*A(15))
      VZT5 = KA(5) + KA(15)*FP5 + KA(25)*FP5*FP5
      PHI5 = VZT5/(KRAD(5)*NC5)
      PSIP5=FUN1(11,PHI5,19)
      PD5 = PV4*(1.+PSIP5*KNR(5)/TV4)**3.5
      PV5 = PD5
      PSIT5=FUN1(12,PHI5,21)
```

Table A-2. Reduced-Order Component Model (Continued)

```
      TD5 = TV4*KNR(5)*PSIT5
      TV5 = TD5
      RTH5 = SQRT(TV5/518.7)
      WBL5 = KBLD(5)*ABL*PV5/(K3*RTH5)
C
C   STAGE SIX
C
      WD6 = WD5-WBL5
      NC6 = N/RTH5
      DEL5 = PV5/14.7
      FP6 = WD6*RTH5/(DEL5*A(16))
      VZT6 = KA(6) + KA(16)*FP6 + KA(26)*FP6*FP6
      PHI6 = VZT6/(KRAD(6)*NC6)
      PSIP6=FUN1(13,PHI6,23)
      PD6 = PV5*(1.+PSIP6*KNR(6)/TV5)**3.5
      PV6=PD6
      PSIT6=FUN1(14,PHI6,25)
      TD6 = TV5+KNR(6)*PSIT6
      TV6=TD6
C
C   STAGE SEVEN
C
      WD7=WD6
      RTH6 = SQRT(TV6/518.7)
      NC7 = N/RTH6
      DEL6 = PV6/14.7
      FP7 = WD7*RTH6/(DEL6*A(17))
      VZT7 = KA(7) + KA(17)*FP7 + KA(27)*FP7*FP7
      PHI7 = VZT7/(KRAD(7)*NC7)
      PSIP7=FUN1(15,PHI7,27)
      PD7 = PV6*(1.+PSIP7*KNR(7)/TV6)**3.5
      PV7=PD7
      PSIT7=FUN1(16,PHI7,29)
      TD7 = TV6+KNR(7)*PSIT7
      TV7=TD7
C
C   STAGE EIGHT
C
      WD8=WD7
      RTH7 = SQRT(TV7/518.7)
      NC8 = N/RTH7
      DEL7 = PV7/14.7
      FP8 = WD8*RTH7/(DEL7*A(18))
      VZT8 = KA(8) + KA(18)*FP8 + KA(28)*FP8*FP8
      PHI8 = VZT8/(KRAD(8)*NC8)
      PSIP8=FUN1(17,PHI8,31)
      PD8 = PV7*(1.+PSIP8*KNR(8)/TV7)**3.5
      PV8=PD8
      PSIT8=FUN1(18,PHI8,33)
      TD8 = TV7+KNR(8)*PSIT8
      TV8=TD8
C
C   OUTLET GUIDE VANES
C
      WOGV = WD8
      TOGV=TD8
      OGVPR=FUN1(3,NC1N,3)
      POGV=OGVPR*PD8
C
C   COMPRESSOR DISCHARGE
C
```

Table A-2. Reduced-Order Component Model (Continued)

```
      WTC = .033*WDO
      TCD=TOGV
      WCD=WOGV
      PCD=POGV
      TWCD=PCD/KVOLCD
      WDCD=TWCD/TCD
C
C  BURNER
C
      CALL PROCOM(0.,TCD,CPCD,GMCD,GMCDX,HCD,IFA)
      WB=WCD-WTC
      FAB=WF/WB
      NRAT=N/16500.
      KWB=FUN1(20,NRAT,37)
  140 ETABO=ETAB
      HB=HCD+18650.*ETAB*FAB
      TEB=TFNH(2,FAB,HB,TV)
      IF(INIT.EQ.1) TM=TEB
      TMDT=4.5*0.248*(TEB-TM)/(15.*0.12)
      TB=(0.24*WB*TEB-15.*0.12*TMDT)/(0.24*WB)
      DELPB = KWB*WB**2/PCD*(.771*TCD-.085*TB)
      PB=PCD-DELPB
      PBDLTB=PB*(TB-TCD)
      ETAB=FUN1(19,PBDLTB,35)
      IF(ABS(ETAB-ETABO).GT.1.E-10) GO TO 140
      NRTTB = N/SQRT(TB)
      WT=WB+WF
      FAT=WF/(WT+WTC)
      PTPB = PT/PB
      WTTNPB = FUN2(3,PTPB,NRTTB,6)
      WTCAL = WTTNPB*N*PB/TB
      PTERR=WTCAL-WT
      WN=WT+WTC
      DHTNTB = FUN2(4,PTPB,NRTTB,8)
      DHT=N/1000.*DHTNTB*SQRT(TB)
      HT=HB-DHT
      HT=(WT*HT+WTC*HCD)/(WT+WTC)
      TT=TFNH(3,FAT,HT,TV)
      POPT=PB/PT
      WNTKNP=HOKEY(POPT)
      KNA8=5.0405-.0429772*A8+.000126664*A8**2
      WNCAL = WNTKNP*A8*KNA8*PT/SQRT(TT)
      WNERR=WNCAL-WN
      WBLTBL = WBL3*TV3+WBL4*TV4+WBL5*TV5
      DLWHC=HCD*WCD+.24*(WBLTBL-TVO*WDO)
      DLWHT=WT*DHT
      NDT=KSPEED/N*(DLWHT-DLWHC)
      IF(ABS(PTERR).LT.ERROR.AND.ABS(WNERR).LT.ERROR) GO TO 100
C     GRADIENT CALCULATION
      ITER1=ITER1+1
      GO TO (10,20,30,40,50) ITER1
   10 F=PTERR
      G=WNERR
      IF(SENSE SWITCH 5) 11,12
   11 OUTPUT(9) WDO,PVO,TVO,WD1,PD1,TD1,WD2,PD2,TD2,WD3,PD3,TD3,WBL3,WD4
     1,PD4,TD4,WBL4,WD5,PD5,TD5,WBL5,WD6,PD6,TD6,WD7,PD7,TD7,WD8,PD8,
     2TD8,WOGV,POGV,TOGV,WTC,PCD,TCD,WCD,HCD,WF,WB,PB,TB,HB,WT,PT,TT,HT,
     3WN,FAB,FAT,ETAB,KNA8,DELPB,NRTTB,WTTNPB,PBDLTB,DHTNTB,DHT,WBLTBL,
     4DLWHC,DLWHT,NDT,N,PT,WDO,PTERR,WNERR,WTCAL,WT,WNCAL,WN,ITER1,ITER2
      OUTPUT(9) TEB,TM,THDT
      IF(SENSE SWITCH 6) 13,12
```

Table A-2. Reduced-Order Component Model (Concluded)

```
   13 CONTINUE
      PAUSE
      READ(5,300) IDUM
      READ(5,300) PT,WDO
  300 FORMAT(2E12.5)
      GO TO 95
   12 ITER2=ITER2+1
      PT=PT+DELPT
      GO TO 99
   20 FX=PTERR
      GX=WNERR
      PT=PT-2.*DELPT
      GO TO 99
   30 FX=(FX-PTERR)/(2.*DELPT)
      GX=(GX-WNERR)/(2.*DELPT)
      PT=PT+DELPT
      WDO=WDO+DELWDO
      GO TO 99
   40 FY=PTERR
      GY=WNERR
      WDO=WDO-2.*DELWDO
      GO TO 99
   50 FY=(FY-PTERR)/(2.*DELWDO)
      GY=(GY-WNERR)/(2.*DELWDO)
      WDO=WDO+DELWDO
      D=FX*GY-GX*FY
      IF(ABS(D).LT.0.000001) STOP 77
      DXX=(-F*GY+G*FY)/D
      DYY=(-G*FX+F*GX)/D
      IF(ABS(DXX).LT.(2.*DELPT)) GO TO 60
      FACTOR=2.*DELPT/ABS(DXX)
      DXX=FACTOR*DXX
      DYY=FACTOR*DYY
   60 IF(ABS(DYY).LT.(2.*DELWDO)) GO TO 70
      FACTOR=2.*DELWDO/ABS(DYY)
      DYY=FACTOR*DYY
      DXX=FACTOR*DXX
   70 PT=PT+DXX
      WDO=WDO+DYY
      ITER1=0
      GO TO 99
  100 CONTINUE
      N = INTGRL(ICN,NDT)
      IF(SENSE SWITCH 5) 110,120
  110 WRITE(9,511) ITER2
  511 FORMAT(1H1,5X,12HCONVERGED IN,I10,12H  ITERATIONS)
      OUTPUT(9) N,WF,AB,BVO,ABL,NDT,PTERR,WNERR,PT,WDO
      WRITE(9,512)
  512 FORMAT(1H1)
  120 CONTINUE
      RETURN
      END
```

```
      FUNCTION HOKEY(POPT)
      IF(POPT.GE.1.) GOTO 1
      IF(POPT.GE..53) HOKEY=POPT**(1./1.4)*SQRT(1.-POPT**(.4/1.4))
      IF(POPT.GE.0..AND.POPT.LE..53) HOKEY=.2588
      RETURN
    1 HOKEY=0.
      RETURN
      END
```

Table A-3. Engine Component Characteristics

FUNCTION F11: ABLB = f [BVOB]

BVOB	ABLB
.00000E 00	.00000E 00
.10000E 00	.18000E 00
.20000E 00	.33000E 00
.25000E 00	.39500E 00
.30000E 00	.45500E 00
.40000E 00	.54500E 00
.50000E 00	.63000E 00
.70000E 00	.78800E 00
.10000E 01	.10000E 01

FUNCTION F12: IGVPR = f [N/N_{MAX}]

N/N_{MAX}	IGVPR
.00000E 00	.99800E 00
.60000E 00	.99800E 00
.65000E 00	.99750E 00
.70000E 00	.99680E 00
.75000E 00	.99570E 00
.80000E 00	.99400E 00
.85000E 00	.99200E 00
.90000E 00	.98980E 00
.95000E 00	.98750E 00
.10000E 01	.98500E 00

FUNCTION F13: OGVPR = f [N/N_{MAX}]

N/N_{MAX}	OGVPR
.00000E 00	.99800E 00
.60000E 00	.99800E 00
.65000E 00	.99750E 00
.70000E 00	.99680E 00
.75000E 00	.99620E 00
.80000E 00	.99570E 00
.85000E 00	.99530E 00
.90000E 00	.99500E 00
.10000E 01	.99500E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F15: $\psi_2^P = f\,[\phi_2]$

ϕ_2	ψ^P_2
.00000E 00	.25000E 00
.45000E 00	.69500E 00
.50000E 00	.74550E 00
.55000E 00	.79200E 00
.56800E 00	.80700E 00
.58000E 00	.81600E 00
.60000E 00	.83100E 00
.62000E 00	.84400E 00
.64000E 00	.85600E 00
.66000E 00	.86600E 00
.68000E 00	.87300E 00
.70000E 00	.87800E 00
.72000E 00	.87900E 00
.73000E 00	.87800E 00
.74000E 00	.86800E 00
.75000E 00	.85300E 00
.76000E 00	.82700E 00
.76700E 00	.78000E 00
.79000E 00	.50000E 00
.80500E 00	.25000E-01

FUNCTION F16: $\psi_2^T = f\,[\phi_2]$

ϕ_2	ψ_2^T
.00000E 00	.29500E 01
.45000E 00	.10000E 01
.50000E 00	.97000E 00
.55000E 00	.95500E 00
.56800E 00	.95300E 00
.58000E 00	.95300E 00
.60000E 00	.95200E 00
.62000E 00	.95600E 00
.64000E 00	.96000E 00
.66000E 00	.97000E 00
.68000E 00	.97500E 00
.70000E 00	.98000E 00
.72000E 00	.98000E 00
.73000E 00	.97800E 00
.74000E 00	.97200E 00
.75000E 00	.96200E 00
.76000E 00	.93500E 00
.76700E 00	.90300E 00
.79000E 00	.62000E 00
.80500E 00	.22000E 00
.82000E 00	-.26000E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F17: $\psi_3^P = f[\phi_3]$

ϕ_3	ψ_3^P
.00000E 00	.55000E 00
.50000E 00	.69300E 00
.53000E 00	.70200E 00
.57000E 00	.71200E 00
.58000E 00	.71500E 00
.60000E 00	.71900E 00
.62000E 00	.72400E 00
.64000E 00	.72800E 00
.65000E 00	.73000E 00
.66000E 00	.73300E 00
.67000E 00	.73400E 00
.68000E 00	.72900E 00
.69000E 00	.71800E 00
.69500E 00	.70400E 00
.69800E 00	.67000E 00
.69900E 00	.62400E 00
.70400E 00	.39400E 00

FUNCTION F18: $\psi_3^T = f[\phi_3]$

ϕ_3	ψ_3^T
.00000E 00	.10600E 01
.50000E 00	.83500E 00
.53000E 00	.82500E 00
.57000E 00	.82000E 00
.58000E 00	.81800E 00
.60000E 00	.82000E 00
.62000E 00	.82200E 00
.64000E 00	.82500E 00
.65000E 00	.82800E 00
.66000E 00	.83100E 00
.67000E 00	.83200E 00
.68000E 00	.83000E 00
.69000E 00	.81800E 00
.69500E 00	.80200E 00
.69800E 00	.71600E 00
.69900E 00	.68500E 00
.70400E 00	.62000E 00
.72000E 00	.40000E 00
.74000E 00	.12300E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F19: $\psi_4^P = f[\phi_4]$

ϕ_4	ψ_4^P
.00000E 00	.88000E 00
.53000E 00	.84200E 00
.55000E 00	.84100E 00
.57000E 00	.83600E 00
.58000E 00	.83000E 00
.60000E 00	.81900E 00
.61000E 00	.81300E 00
.62000E 00	.80700E 00
.63000E 00	.79900E 00
.64000E 00	.79200E 00
.65000E 00	.78300E 00
.65700E 00	.77700E 00
.66000E 00	.77300E 00
.66300E 00	.76600E 00
.66900E 00	.75200E 00
.67500E 00	.73800E 00
.72500E 00	.00000E 00
.77500E 00	-.73800E 00

FUNCTION F110: $\psi_4^T = f[\phi_4]$

ϕ_4	ψ_4^T
.00000E 00	.14650E 01
.53000E 00	.98500E 00
.55000E 00	.96300E 00
.57000E 00	.94800E 00
.58000E 00	.93200E 00
.60000E 00	.92300E 00
.61000E 00	.91400E 00
.62000E 00	.90400E 00
.63000E 00	.89300E 00
.64000E 00	.88400E 00
.65000E 00	.87700E 00
.65700E 00	.87500E 00
.66000E 00	.87500E 00
.66300E 00	.87500E 00
.66900E 00	.88000E 00
.67500E 00	.88500E 00
.68500E 00	.86200E 00
.70000E 00	.62000E 00
.72500E 00	.13000E 00
.77500E 00	-.87000E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F111: $\psi_5^P = f[\phi_5]$

ϕ_5	ψ_4^P
.00000E 00	.70000E 00
.52000E 00	.70000E 00
.54000E 00	.69700E 00
.55800E 00	.69100E 00
.57000E 00	.68500E 00
.58000E 00	.67800E 00
.59000E 00	.67200E 00
.59500E 00	.66700E 00
.60000E 00	.66300E 00
.61000E 00	.64800E 00
.61500E 00	.63600E 00
.62000E 00	.61700E 00
.62500E 00	.57900E 00
.64000E 00	.37200E 00
.66250E 00	.00000E 00
.68500E 00	-.37200E 00

FUNCTION F112: $\psi_5^T = f[\phi_5]$

ϕ_5	ψ_5^T
.00000E 00	.35800E 01
.42500E 00	.10070E 01
.47500E 00	.91200E 00
.52000E 00	.85300E 00
.54000E 00	.82600E 00
.55800E 00	.80500E 00
.57000E 00	.78700E 00
.58000E 00	.77500E 00
.59000E 00	.76600E 00
.59500E 00	.76000E 00
.60000E 00	.74500E 00
.61000E 00	.73000E 00
.61500E 00	.71500E 00
.62000E 00	.70000E 00
.62500E 00	.67500E 00
.64000E 00	.51000E 00
.66250E 00	.79000E-01
.68500E 00	-.40200E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F113: $\psi_6^P = f\,[\phi_6]$

ϕ_6	ψ_6^P
.00000E 00	.61600E 00
.50000E 00	.61600E 00
.52000E 00	.61200E 00
.53500E 00	.60500E 00
.55000E 00	.58500E 00
.57000E 00	.55000E 00
.58000E 00	.52500E 00
.60000E 00	.47800E 00
.61000E 00	.45000E 00
.62500E 00	.40000E 00
.67500E 00	.20000E 00
.72500E 00	.00000E 00
.77500E 00	-.20000E 00

FUNCTION F114: $\psi_6^T = f\,[\phi_6]$

ϕ_6	ψ_6^T
.00000E 00	.82000E 00
.50000E 00	.70500E 00
.52000E 00	.69500E 00
.53500E 00	.68300E 00
.55000E 00	.66600E 00
.57000E 00	.63200E 00
.58000E 00	.61200E 00
.60000E 00	.56200E 00
.61000E 00	.53000E 00
.62500E 00	.48200E 00
.67500E 00	.29700E 00
.72500E 00	.75000E-01
.77500E 00	-.14700E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F115: $\psi_7^P = f[\phi_7]$

ϕ_7	ψ_7^P
.00000E 00	.48600E 00
.47500E 00	.48600E 00
.48500E 00	.48600E 00
.50000E 00	.48400E 00
.51500E 00	.48000E 00
.52500E 00	.46500E 00
.55000E 00	.41500E 00
.56500E 00	.37500E 00
.57500E 00	.34500E 00
.59000E 00	.29500E 00
.59500E 00	.27500E 00
.60000E 00	.25500E 00
.62500E 00	.15500E 00
.66000E 00	.00000E 00
.69500E 00	-.15500E 00

FUNCTION F116: $\psi_7^T = f[\phi_7]$

ϕ_7	ψ_7^T
.00000E 00	.56200E 00
.50000E 00	.56000E 00
.51500E 00	.55200E 00
.52500E 00	.53700E 00
.55000E 00	.48700E 00
.56500E 00	.44300E 00
.57500E 00	.41200E 00
.59000E 00	.36200E 00
.59500E 00	.34200E 00
.60000E 00	.32300E 00
.62500E 00	.22000E 00
.66000E 00	.00000E 00
.69500E 00	-.25200E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F117: $\psi_8^P = f\,[\phi_8]$

ϕ_8	ψ_8^P
.45000E 00	.40000E 00
.46000E 00	.48400E 00
.46500E 00	.48200E 00
.47500E 00	.47600E 00
.49000E 00	.46000E 00
.50000E 00	.43500E 00
.51000E 00	.39400E 00
.52500E 00	.33000E 00
.54000E 00	.26500E 00
.55000E 00	.22500E 00
.56500E 00	.16300E 00
.57500E 00	.12200E 00
.60000E 00	.25000E-01
.60550E 00	.00000E 00
.66100E 00	-.22500E 00

FUNCTION F118: $\psi_8^T = f\,[\phi_8]$

ϕ_8	ψ_8^T
.00000E 00	.56000E 00
.45000E 00	.56000E 00
.46000E 00	.56000E 00
.46500E 00	.56000E 00
.47500E 00	.56000E 00
.49000E 00	.53500E 00
.50000E 00	.50700E 00
.51000E 00	.46500E 00
.52500E 00	.40000E 00
.54000E 00	.32000E 00
.55000E 00	.27000E 00
.56500E 00	.20500E 00
.57500E 00	.16000E 00
.60000E 00	.45000E-01
.60550E 00	.00000E 00
.66100E 00	-.45200E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F119: $\eta_B = f\,[PB \cdot (TB-TCD)]$

PB·(TB-TCD)	η_B
.00000E 00	.79450E 00
.90000E 04	.88000E 00
.15000E 05	.93100E 00
.13250E 05	.95500E 00
.24000E 05	.97100E 00
.30000E 05	.98100E 00
.36500E 05	.98700E 00
.47500E 05	.99000E 00
.55000E 05	.99000E 00
.72500E 05	.98620E 00
.95000E 05	.98320E 00
.12500E 06	.98100E 00
.14000E 06	.98050E 00
.16000E 06	.98000E 00

FUNCTION F120: $KWB = f\,[N/N_{MAX}]$

N/N_{MAX}	KWB
.60000E 00	.72600E-03
.70000E 00	.70700E-03
.80000E 00	.69800E-03
.85000E 00	.69000E-03
.90000E 00	.69600E-03
.97000E 00	.69600E-03
.10000E 01	.73800E-03

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F1: BVOB = f [N/N_{MAX}, T_0]

N/N_{MAX} \ T_0	.48000E 03	.49250E 03	.50300E 03	.51850E 03	.53000E 03
.00000E 00	.10000E 01	.10000E 01	.10000E 01	.10000E 01	.10000E 01
.80000E 00	.10000E 01	.10000E 01	.10000E 01	.10000E 01	.10000E 01
.82000E 00	.83500E 00	.83500E 00	.83500E 00	.83500E 00	.83500E 00
.84000E 00	.70500E 00	.69700E 00	.69000E 00	.68400E 00	.67800E 00
.86000E 00	.592[illegible]0E 00	.58000E 00	.56800E 00	.55500E 00	.53500E 00
.88000E 00	.52000E 00	.50000E 00	.47000E 00	.43500E 00	.39500E 00
.90000E 00	.46800E 00	.43200E 00	.39000E 00	.32500E 00	.26500E 00
.92000E 00	.41500E 00	.36500E 00	.30000E 00	.22000E 00	.13000E 00
.94000E 00	.34500E 00	.27500E 00	.19000E 00	.10500E 00	.00000E 00
.95500E 00	.27500E 00	.19000E 00	.10000E 00	.00000E 00	.00000E 00
.97000E 00	.20000E 00	.10000E 00	.00000E 00	.00000E 00	.00000E 00
.98500E 00	.10000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.10000E 01	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00

Table A-3. Engine Component Characteristics (Continued)

FUNCTION F2: $\psi_2^P = f[\phi_2, IGV]$

ϕ_2 \ IGV	.00000E 00	.50000E 00	.75000E 00	.10000E 01
.00000E 00	.42000E 00	.30000E 00	.28000E 00	.26000E 00
.45000E 00	.84500E 00	.86400E 00	.83000E 00	.79200E 00
.47500E 00	.87000E 00	.89200E 00	.86100E 00	.82200E 00
.50000E 00	.89300E 00	.91000E 00	.88200E 00	.84300E 00
.52500E 00	.90900E 00	.92000E 00	.88900E 00	.85000E 00
.55000E 00	.92500E 00	.91500E 00	.88500E 00	.84900E 00
.57500E 00	.93000E 00	.90300E 00	.87000E 00	.84000E 00
.60000E 00	.93000E 00	.87500E 00	.84800E 00	.81300E 00
.62500E 00	.92000E 00	.84000E 00	.82000E 00	.78200E 00
.65000E 00	.90500E 00	.79500E 00	.78700E 00	.74700E 00
.67500E 00	.88300E 00	.74600E 00	.74600E 00	.70500E 00
.70000E 00	.85900E 00	.67500E 00	.67500E 00	.65600E 00
.72500E 00	.82700E 00	.61500E 00	.61500E 00	.60000E 00
.75000E 00	.77000E 00	.51000E 00	.51000E 00	.51000E 00
.77500E 00	.61500E 00	.36200E 00	.36200E 00	.36200E 00
.79000E 00	.40000E 00	.26500E 00	.26500E 00	.26500E 00
.80500E 00	.25000E-01	.25000E-01	.25000E-01	.25000E-01

Table A-3. Engine Compone

FUNCTION F3: $\frac{WT \cdot TB}{N \cdot PB} = f \left[\frac{PT}{PB}, \sqrt{} \right.$

PT/PB \ N/√TB	.10000E 03	.15000E 03	.20000E 03	.24000E 03	.26000E 03	.28000E 03	.30000E 03
.00000E 00	.22480E 00	.14870E 00	.11120E 00	.92500E-01	.83300E-01	.77300E-01	.72000E-01
.10000E 00	.22480E 00	.14870E 00	.11120E 00	.92500E-01	.83300E-01	.77300E-01	.72000E-01
.20000E 00	.22480E 00	.14870E 00	.11100E 00	.92500E-01	.83300E-01	.77300E-01	.72000E-01
.30000E 00	.22390E 00	.14800E 00	.11000E 00	.91500E-01	.83300E-01	.77300E-01	.72000E-01
.35000E 00	.22380E 00	.14700E 00	.10910E 00	.90600E-01	.83200E-01	.77200E-01	.71900E-01
.40000E 00	.22270E 00	.14600E 00	.10830E 00	.89800E-01	.82800E-01	.76900E-01	.71600E-01
.45000E 00	.22110E 00	.14610E 00	.10750E 00	.89100E-01	.81900E-01	.76000E-01	.70800E-01
.50000E 00	.21920E 00	.14390E 00	.10630E 00	.88000E-01	.80800E-01	.74900E-01	.69700E-01
.55000E 00	.21690E 00	.14230E 00	.10470E 00	.86400E-01	.79500E-01	.73500E-01	.68300E-01
.60000E 00	.21430E 00	.13960E 00	.10240E 00	.84200E-01	.77100E-01	.71300E-01	.66400E-01
.70000E 00	.20410E 00	.12970E 00	.93000E-01	.74900E-01	.68600E-01	.62800E-01	.58000E-01
.80000E 00	.16310E 00	.99[illegible]00E-01	.68700E-01	.55000E-01	.50500E-01	.44[illegible]00E-01	.41000E-01
.90000E 00	.88700E-01	.53200E-01	.37800E-01	.28500E-01	.26500E-01	.22400E-01	.21300E-01
.10000E 01	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00

FUNCTION F4: $\frac{\Delta HT}{N\sqrt{TB}} = f \left[\frac{PT}{PB}, \right.$

PT/PB \ N/√TB	.10000E 03	.15000E 03	.20000E 03	.24000E 03	.26000E 03	.28000E 03	.30000E 03
.00000E 00	.26000E 00	.24900E 00	.23600E 00	.22400E 00	.21800E 00	.21100E 00	.20500E 00
.10000E 00	.26000E 00	.24900E 00	.23600E 00	.22400E 00	.21800E 00	.21100E 00	.20500E 00
.20000E 00	.26000E 00	.24900E 00	.23600E 00	.22400E 00	.21800E 00	.21100E 00	.20500E 00
.30000E 00	.26000E 00	.24900E 00	.22900E 00	.20900E 00	.20300E 00	.20000E 00	.19600E 00
.35000E 00	.26000E 00	.24900E 00	.20700E 00	.19000E 00	.18500E 00	.18000E 00	.17500E 00
.40000E 00	.26000E 00	.23200E 00	.18800E 00	.17100E 00	.16600E 00	.16100E 00	.15600E 00
.45000E 00	.26000E 00	.20900E 00	.17100E 00	.15400E 00	.14800E 00	.14200E 00	.13700E 00
.50000E 00	.25000E 00	.18800E 00	.15400E 00	.13800E 00	.13100E 00	.12600E 00	.12100E 00
.55000E 00	.22300E 00	.16700E 00	.13700E 00	.12200E 00	.11500E 00	.11000E 00	.10500E 00
.60000E 00	.19700E 00	.14700E 00	.12000E 00	.10600E 00	.10000E 00	.94900E-01	.90100E-01
.70000E 00	.14700E 00	.10800E 00	.87700E-01	.76200E-01	.70800E-01	.66000E-01	.61500E-01
.80000E 00	.96400E-01	.70100E-01	.56[illegible]00E-01	.47700E-01	.44100E-01	.40600E-01	.37600E-01
.90000E 00	.47600E-01	.33800E-01	.25000E-01	.21700E-01	.19800E-01	.18300E-01	.16300E-01
.10000E 01	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00

a

...ne Component Characteristics (Continued)

$$\frac{WT \cdot TB}{N \cdot PB} = f\left[\frac{PT}{PB}, \frac{N}{\sqrt{TB}}\right]$$

.30000E 03	.32000E 03	.34000E 03	.36000E 03	.38000E 03	.40000E 03	.42000E 03	.44000E 03
.72000E-01	.67400E-01	.63300E-01	.59700E-01	.56400E-01	.53500E-01	.50800E-01	.48400E-01
.72000E-01	.67400E-01	.63300E-01	.59700E-01	.56400E-01	.53500E-01	.50800E-01	.48400E-01
.72000E-01	.67400E-01	.63300E-01	.59700E-01	.56400E-01	.53500E-01	.50800E-01	.48400E-01
.72000E-01	.67400E-01	.63300E-01	.59700E-01	.56400E-01	.53500E-01	.50800E-01	.48400E-01
.71900E-01	.67300E-01	.63200E-01	.59600E-01	.56300E-01	.53300E-01	.50700E-01	.48400E-01
.71500E-01	.67000E-01	.63000E-01	.59300E-01	.56000E-01	.53100E-01	.50500E-01	.48100E-01
.70800E-01	.66300E-01	.62300E-01	.58700E-01	.55400E-01	.52400E-01	.49700E-01	.47300E-01
.69700E-01	.65100E-01	.61200E-01	.57600E-01	.54500E-01	.51600E-01	.49000E-01	.46500E-01
.68300E-01	.63900E-01	.60000E-01	.56600E-01	.53500E-01	.50700E-01	.47900E-01	.45200E-01
.66400E-01	.62200E-01	.58500E-01	.55200E-01	.52000E-01	.48900E-01	.45600E-01	.42400E-01
.58000E-01	.53700E-01	.50100E-01	.46600E-01	.43800E-01	.40800E-01	.38200E-01	.36100E-01
.41000E-01	.37700E-01	[illegible]	.33100E-01	.32100E-01	.31000E-01	.30200E-01	.29600E-01
.21300E-01	.19000E-01	[illegible]	.17400E-01	.17000E-01	.16600E-01	.16200E-01	.15800E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00

$$\frac{\Delta HT}{N\sqrt{TB}} = f\left[\frac{PT}{PB}, \frac{N}{\sqrt{TB}}\right]$$

.30000E 03	.32000E 03	.34000E 03	.36000E 03	.38000E 03	.40000E 03	.42000E 03	.44000E 03
.20500E 00	.19800E 00	.19000E 00	.18300E 00	.17600E 00	.16800E 00	.16100E 00	.15300E 00
.20500E 00	.19800E 00	.19000E 00	.18300E 00	.17600E 00	.16800E 00	.16100E 00	.15300E 00
.20500E 00	.19800E 00	.19000E 00	.18300E 00	.17600E 00	.16800E 00	.16100E 00	.15300E 00
.19600E 00	.19100E 00	.18400E 00	.17500E 00	.16700E 00	.16000E 00	.15300E 00	.14600E 00
.17500E 00	.17000E 00	.16400E 00	.15600E 00	.14900E 00	.14200E 00	.13600E 00	.12900E 00
.15600E 00	.15100E 00	.14500E 00	.13800E 00	.13200E 00	.12600E 00	.12000E 00	.11300E 00
.13700E 00	.13300E 00	.12700E 00	.12100E 00	.11600E 00	.11000E 00	.10300E 00	.95500E-01
.12100E 00	.11600E 00	.11100E 00	.10500E 00	.99600E-01	.93000E-01	.85700E-01	.78200E-01
.10500E 00	.10000E 00	.95300E-01	.90200E-01	.84100E-01	.76800E-01	.68800E-01	.62800E-01
.90100E-01	.85600E-01	.81000E-01	.76000E-01	.69400E-01	.61800E-01	.54600E-01	.49800E-01
.61500E-01	.57000E-01	.55500E-01	.51300E-01	.43800E-01	.39200E-01	.35100E-01	.31800E-01
.37600E-01	.34700E-01	.32000E-01	.29600E-01	.25200E-01	.21700E-01	.18300E-01	.16300E-01
.16300E-01	.14700E-01	.13200E-01	.12000E-01	.10100E-01	.82000E-02	.60000E-02	.48000E-02
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00

b

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Table A-3. Engine Component Characteristics (Concluded)

FUNCTION F5: $\psi_2{}^T = f\ [\psi_2, IGV]$

ψ_2 \ IGV	.00000E 00	.50000E 00	.75000E 00	.10000E 01
.00000E 00	.84000E 01	.60000E 01	.56000E 01	.52000E 01
.45000E 00	.11520E 01	.11770E 01	.11320E 01	.10800E 01
.47500E 00	.11250E 01	.11550E 01	.11130E 01	.10630E 01
.50000E 00	[illegible]	.11300E 01	.10950E 01	.10470E 01
.52500E 00	.10950E 01	.11100E 01	.10720E 01	.10260E 01
.55000E 00	.10850E 01	.10730E 01	.10380E 01	.91600E 00
.57500E 00	.10720E 01	.10390E 01	.10000E 01	.96700E 00
.60000E 00	.10580E 01	.99500E 00	.96500E 00	.92500E 00
.62500E 00	.10380E 01	.94800E 00	.92500E 00	.88200E 00
.65000E 00	.10170E 01	.89300E 00	.88400E 00	.83900E 00
.67500E 00	.99100E 00	.83800E 00	.83800E 00	.79200E 00
.70000E 00	.96500E 00	.75800E 00	.75800E 00	.73700E 00
.72500E 00	.93400E 00	.69500E 00	[illegible]	.67700E 00
.75000E 00	.87500E 00	.58000E 00	.58000E 00	.58000E 00
.77500E 00	.72500E 00	.42600E 00	.42500E 00	.42600E 00
.79000E 00	.55100E 00	.36550E 00	.36550E 00	.36550E 00
.82500E 00	.48000E-01	.48000E-01	.48000E-01	.48000E-01

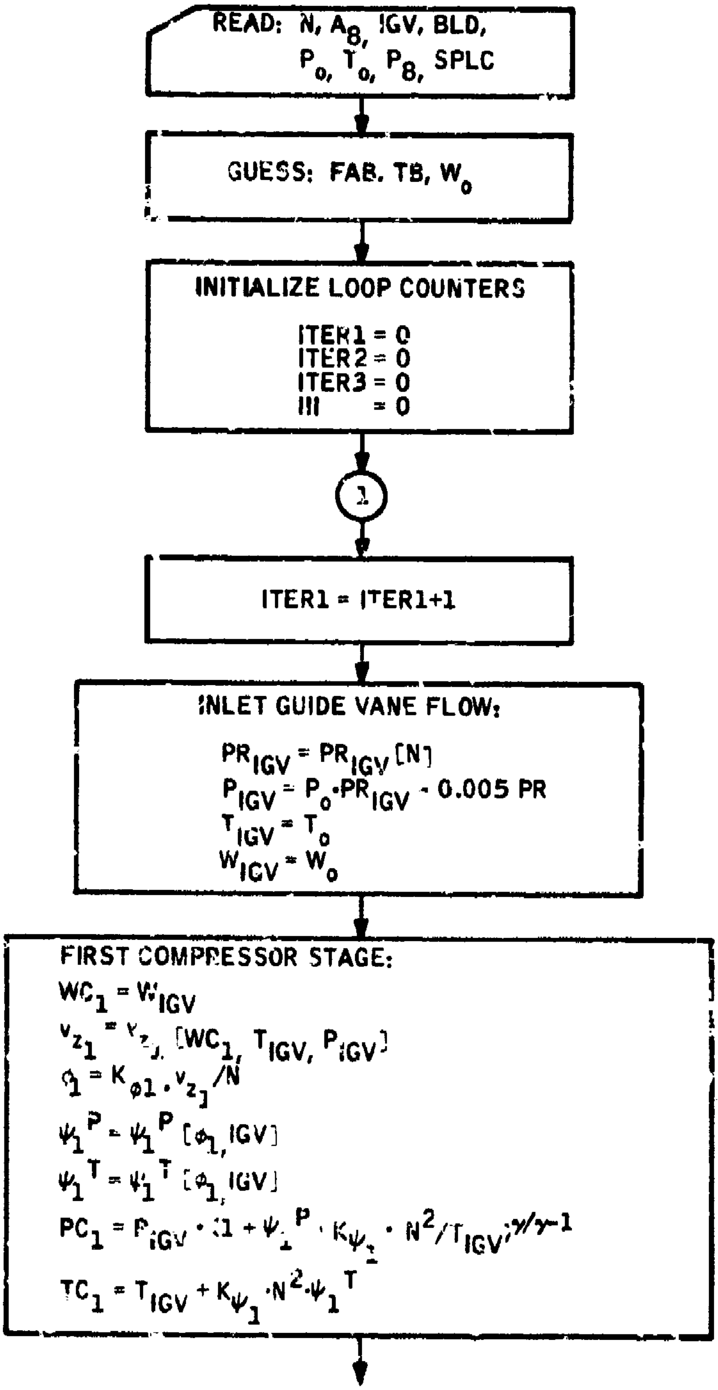


Figure A-1. Trim Routine Flow Chart (Steady-State Trim)

SECOND COMPRESSOR STAGE:

$$WC_2 = WC_1$$
$$v_{z_2} = v_{z_2}\,[WC_2,\ TC_1,\ PC_1]$$
$$\phi_2 = K_{\phi_2} \cdot v_{z_2}/N$$
$$\psi_2{}^P = \psi_2{}^P\,[\phi_2]$$
$$\psi_2{}^T = \psi_2{}^T\,[\phi_2]$$
$$PC_2 = PC_1 \cdot (1 + \psi_2{}^P \cdot K_{\psi_2} \cdot N^2/TC_2)^{\gamma/\gamma-1}$$
$$TC_2 = TC_1 + K_{\psi_2} \cdot N^2 \cdot \psi_2{}^T$$

↓

THIRD COMPRESSOR STAGE:

$$WC_3 = WC_2$$
$$v_{z_3} = v_{z_3}\,[WC_3,\ TC_2,\ PC_2]$$
$$\phi_3 = K_{\phi_3} \cdot v_{z_3}/N$$
$$\psi_3{}^P = \psi_3{}^P\,[\phi_3]$$
$$\psi_3{}^T = \psi_3{}^T\,[\phi_3]$$
$$PC_3 = PC_2 \cdot (1 + \psi_3{}^P \cdot K_{\psi_3} \cdot N^2/TC_3)^{\gamma/\gamma-1}$$
$$TC_3 = TC_2 + K_{\psi_3} \cdot N^2 \cdot \psi_3{}^T$$
$$WBL_3 = KBLD_3 \cdot BLD \cdot PC_3/\sqrt{TC_3}$$

↓

FOURTH COMPRESSOR STAGE:

$$WC_4 = WC_3 - WBL_3$$

⋮

↓

FIFTH - EIGHTH COMPRESSOR STAGES:

⋮

↓

Figure A-1b. Trim Routine Flow Chart (Steady-State Trim)

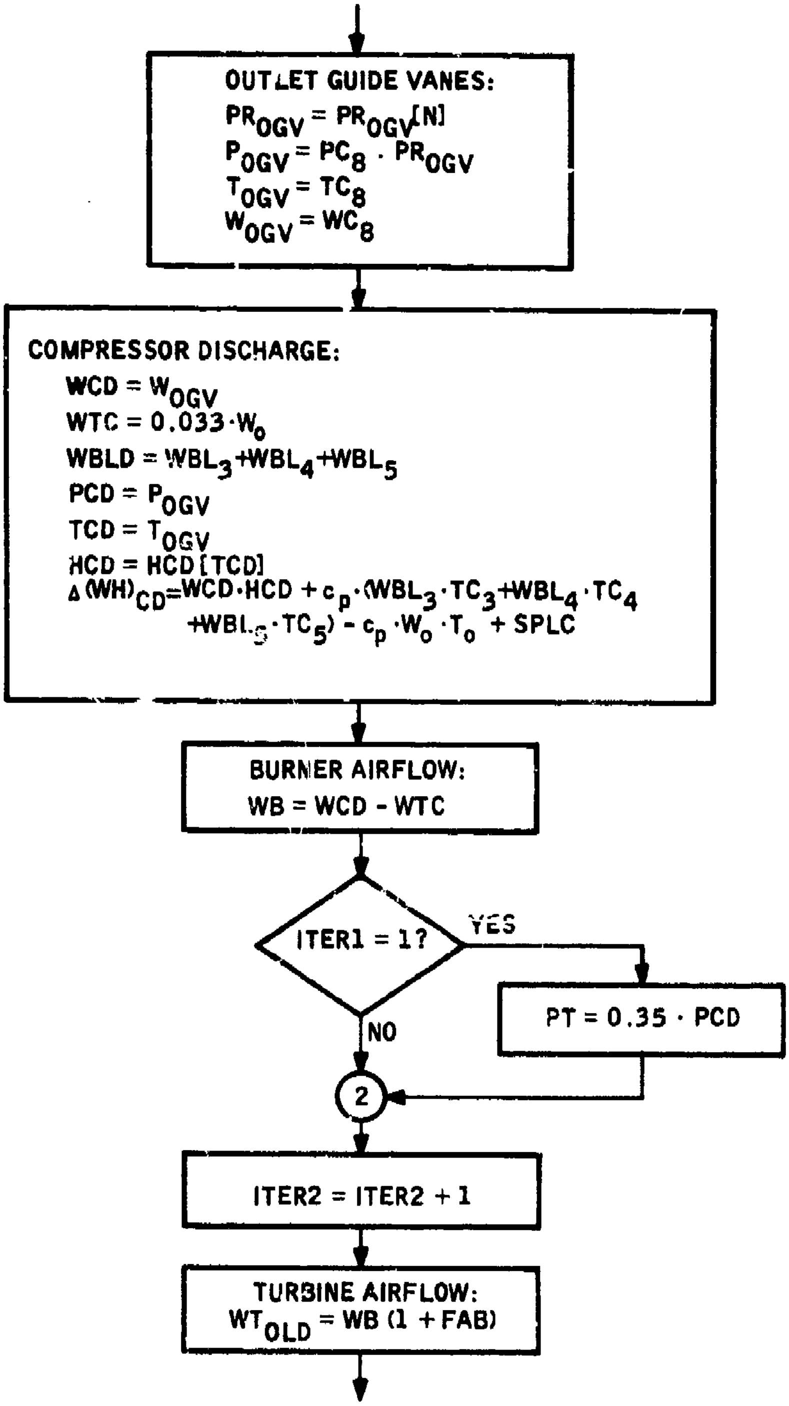


Figure A-1c. Trim Routine Flow Chart (Steady-State Trim)

3

ITER3 = ITER3 + 1

BURNER CONDITIONS:

$$\Delta PB = \frac{KB \cdot WB^2}{PCD}(0.771\ TCD - 0.085\ TB)$$

$$PB = PCD - \Delta PB$$

$$PBDTB = PB\ (TB - TCD)$$

$$\eta_B = \eta_B\ [PBDTB]$$

TURBINE ENTHALPY DROP:

$$\frac{\Delta HT}{N\sqrt{TB}} = \frac{\Delta HT}{N\sqrt{TB}}\left[\frac{PT}{PB}, \frac{N}{\sqrt{TB}}\right]$$

$$\Delta HT = \left(\frac{\Delta HT}{N\sqrt{TB}}\right) \cdot N \cdot \sqrt{TB}$$

4

BURNER ENTHALPY:
GB = HB [FAB, TB]

COMPUTE TURBINE AIRFLOW FROM HEAT EQN:

$$\Sigma\dot{Q}_{BURNER} = \Sigma(WH)_{BURNER} = 0$$

$$WT_1 = \frac{WB\ (h_{FUEL} \cdot \eta_B - HCD)}{(h_{FUEL} \cdot \eta_B - HB)}$$

TURBINE AIRFLOW ERROR:

$$WT_{ERROR} = |WT_1 - WT_{OLD}|$$

Figure A-1d. Trim Routine Flow Chart (Steady-State Trim)

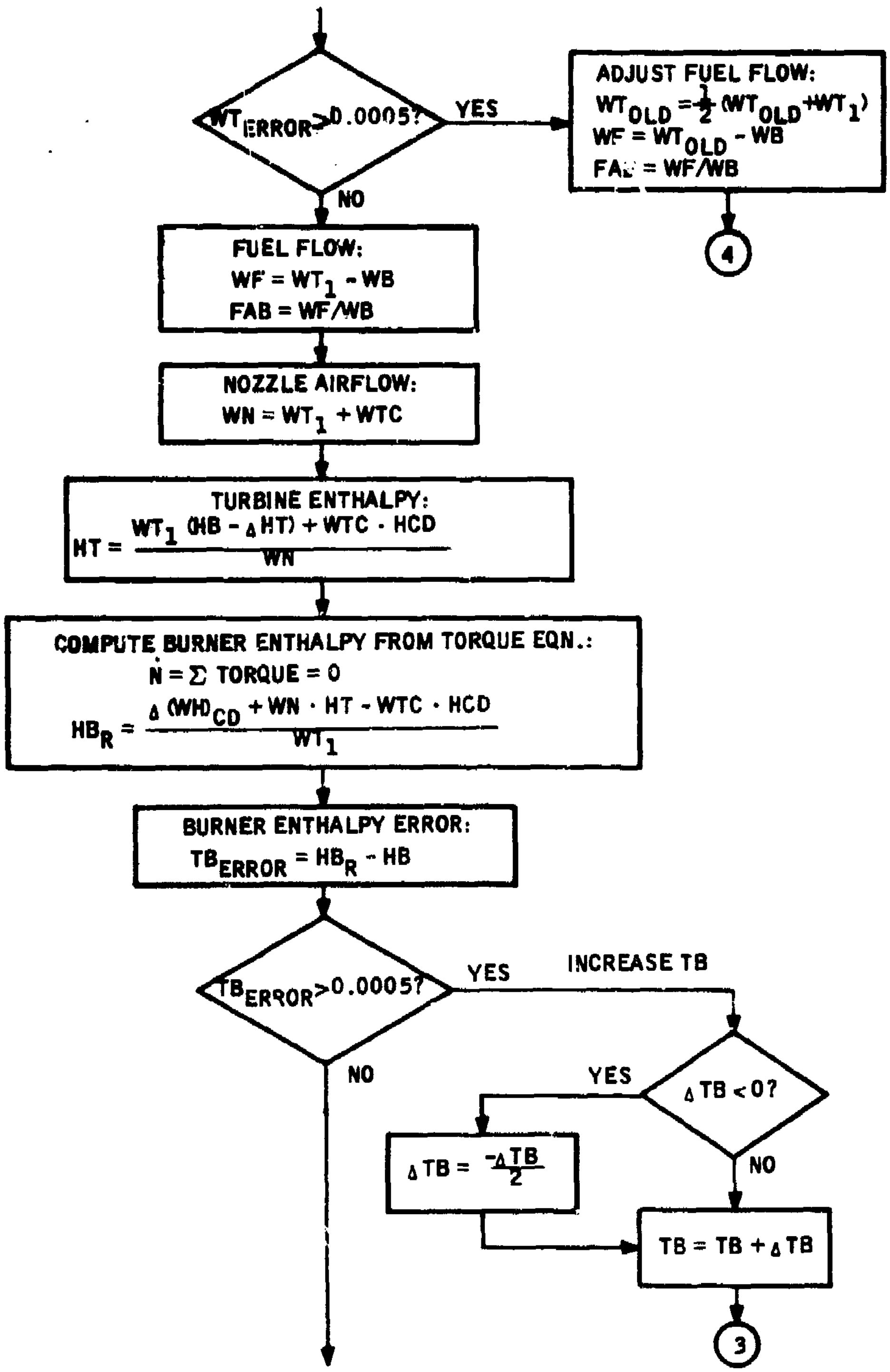


Figure A-1e. Trim Routine Flow Chart (Steady-State Trim)

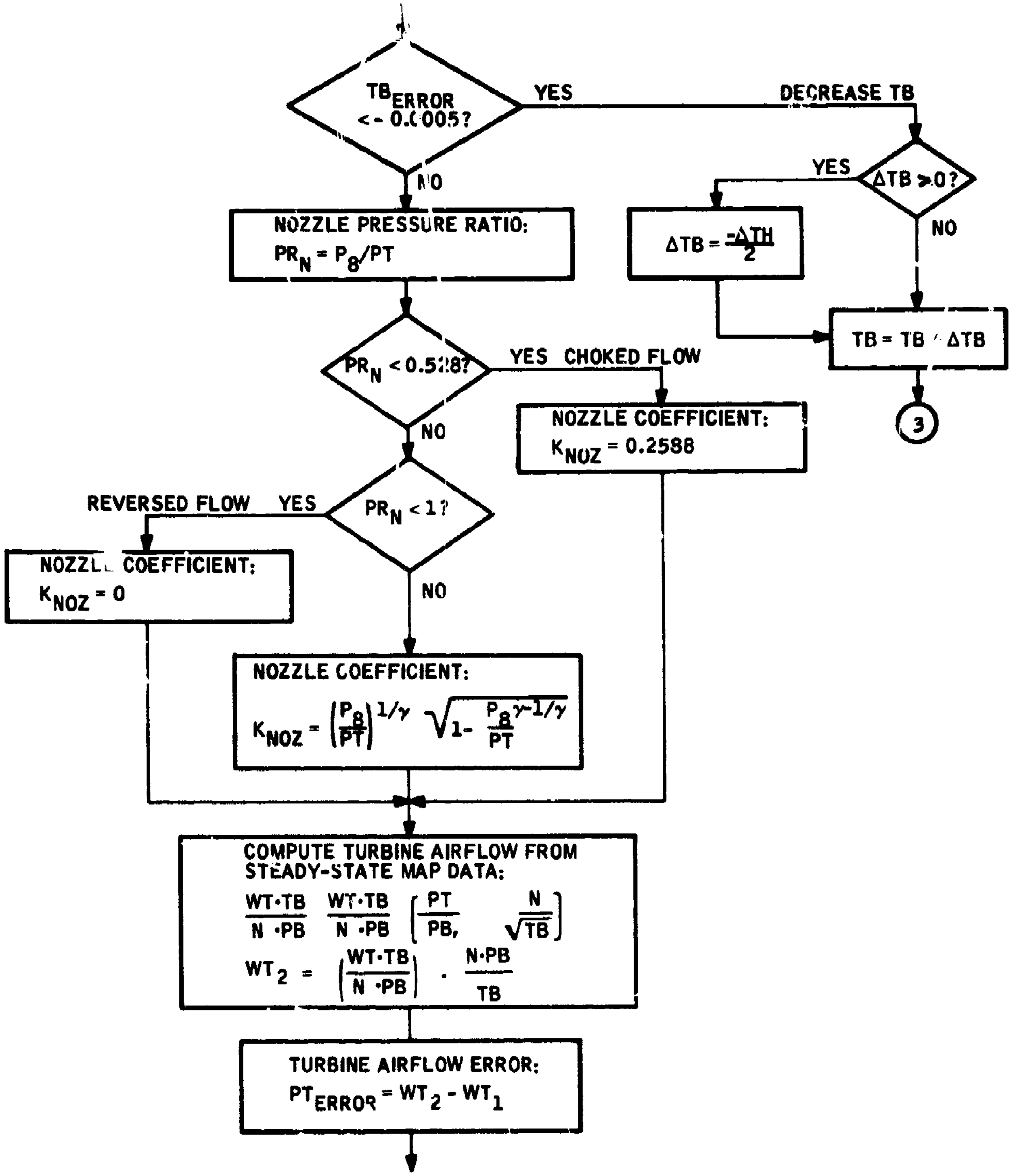


Figure A-1f. Trim Routine Flow Chart (Steady-State Trim)

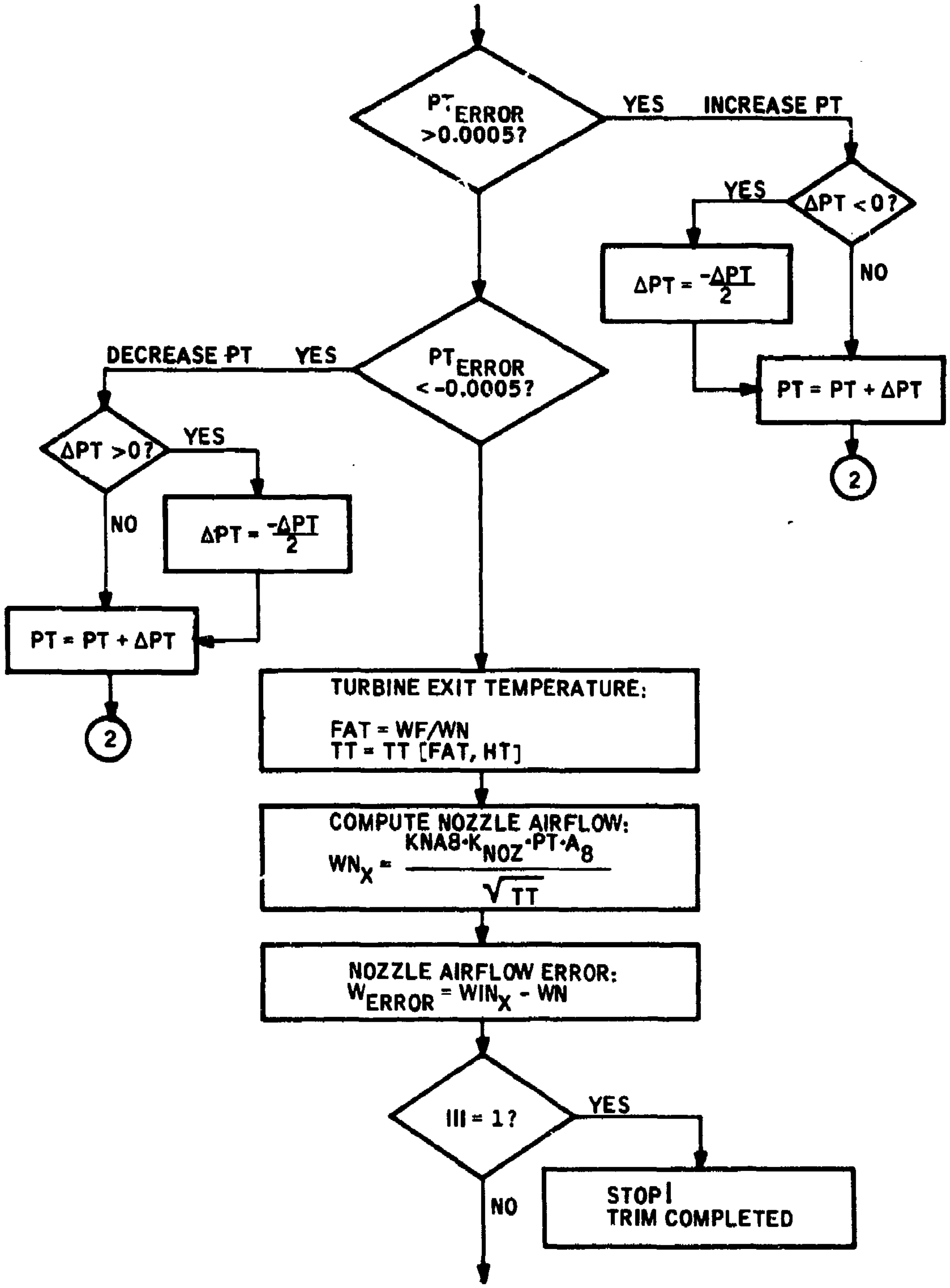


Figure A-1g. Trim Routine Flow Chart (Steady-State Trim)

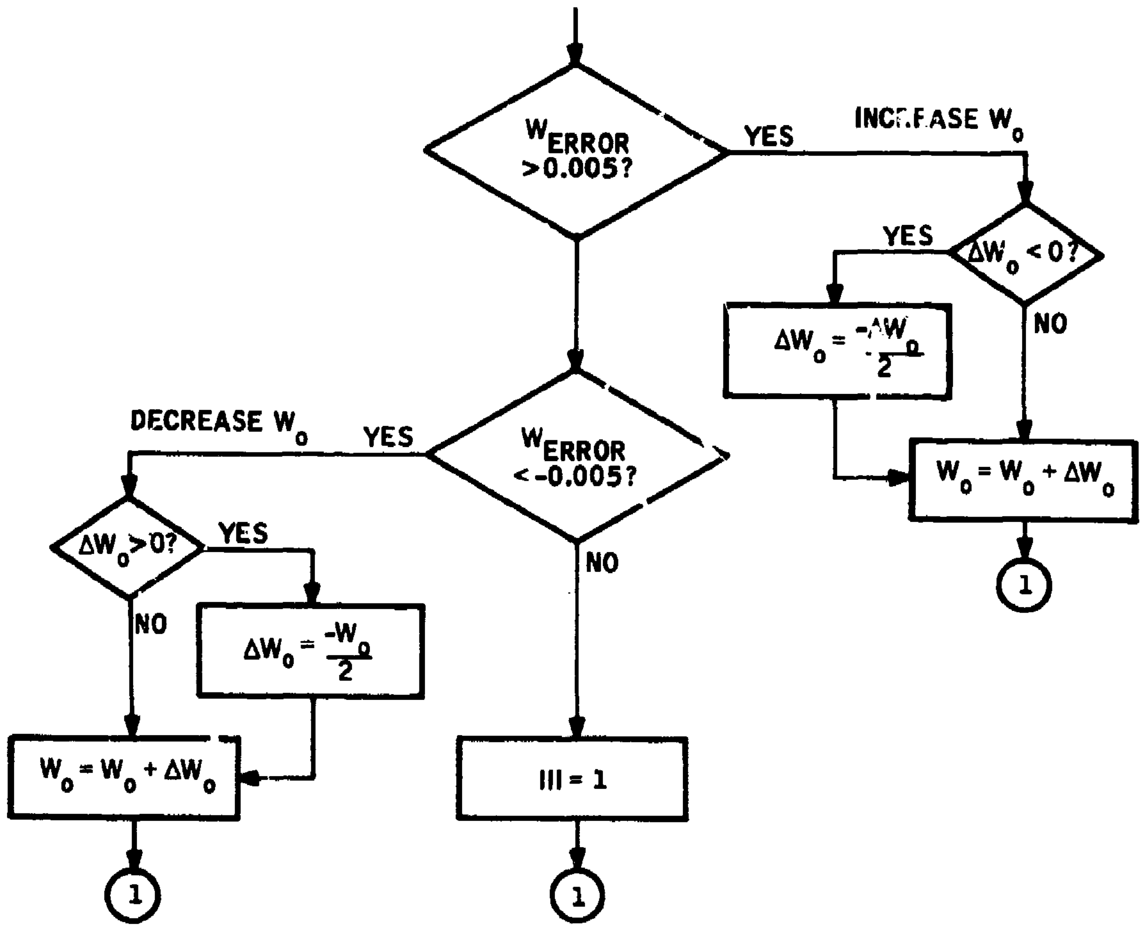


Figure A-1h. Trim Routine Flow Chart (Steady-State Trim)

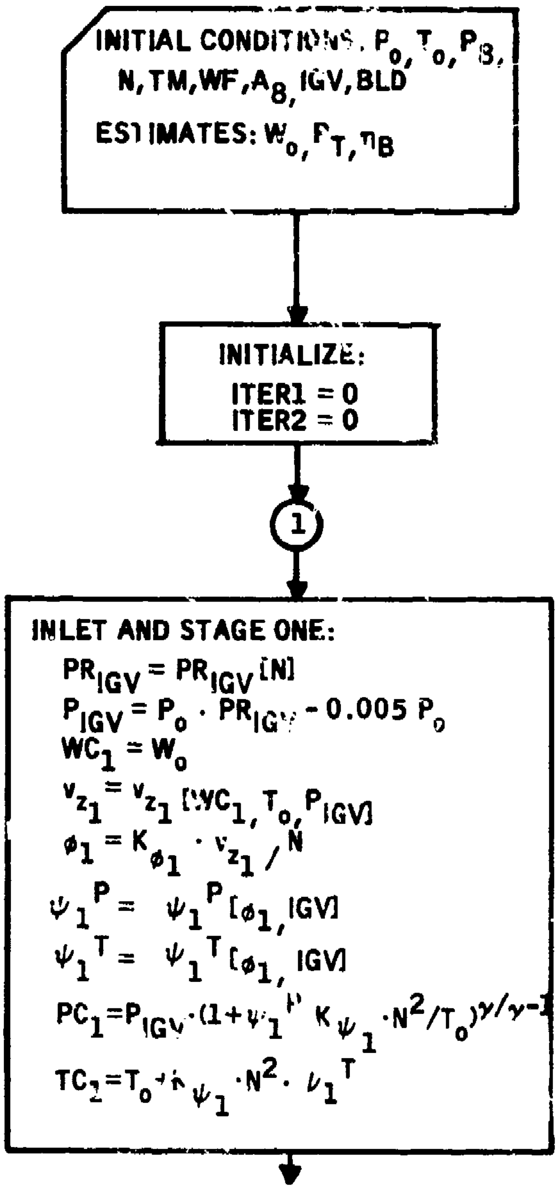


Figure A-2. Subroutine Dynamic Flow Chart

STAGE TWO:

$$WC_2 = WC_1$$

$$v_{z_2} = v_{z_2}[WC_{2_1} TC, PC_1]$$

$$\phi_2 = K_{\phi_2} \cdot v_{z_2} / N$$

$$\psi_2^P = \psi_2^P[\phi_2]$$

$$\psi_2^T = \psi_2^T[\phi_2]$$

$$PC_2 = PC_1 \cdot (1 + \psi_2^P \cdot K_{\psi_2} \cdot N^2 / TC_1)^{\gamma/\gamma-1}$$

$$TC_2 = TC_1 + K_{\psi_2} \cdot N^2 \cdot \psi_2^T$$

STAGE THREE:

$$WC_3 = WC_2$$

$$v_{z_3} = v_{z_3}[WC_{3_1} TC_{2_1} PC_2]$$

$$\phi_3 = K_{\phi_3} \cdot v_{z_3} / N$$

$$\psi_3^P = \psi_3^P[\phi_3]$$

$$\psi_3^T = \psi_3^T[\phi_3]$$

$$PC_3 = PC_2 \cdot (1 + \psi_3^P \cdot K_{\psi_3} \cdot N^2 / TC_2)^{\gamma/\gamma-1}$$

$$TC_3 = TC_2 + K_{\psi_3} \cdot N^2 \cdot \psi_3^T$$

$$WBL_3 = KBLD_3 \cdot BLD \cdot PC_3 / \sqrt{TC_3}$$

STAGE FOUR:

$$WC_4 = WC_3 - WBL_3$$

⋮

STAGES FIVE - EIGHT:

⋮

Figure A-2. Subroutine Dynamic Flow Chart (Continued)

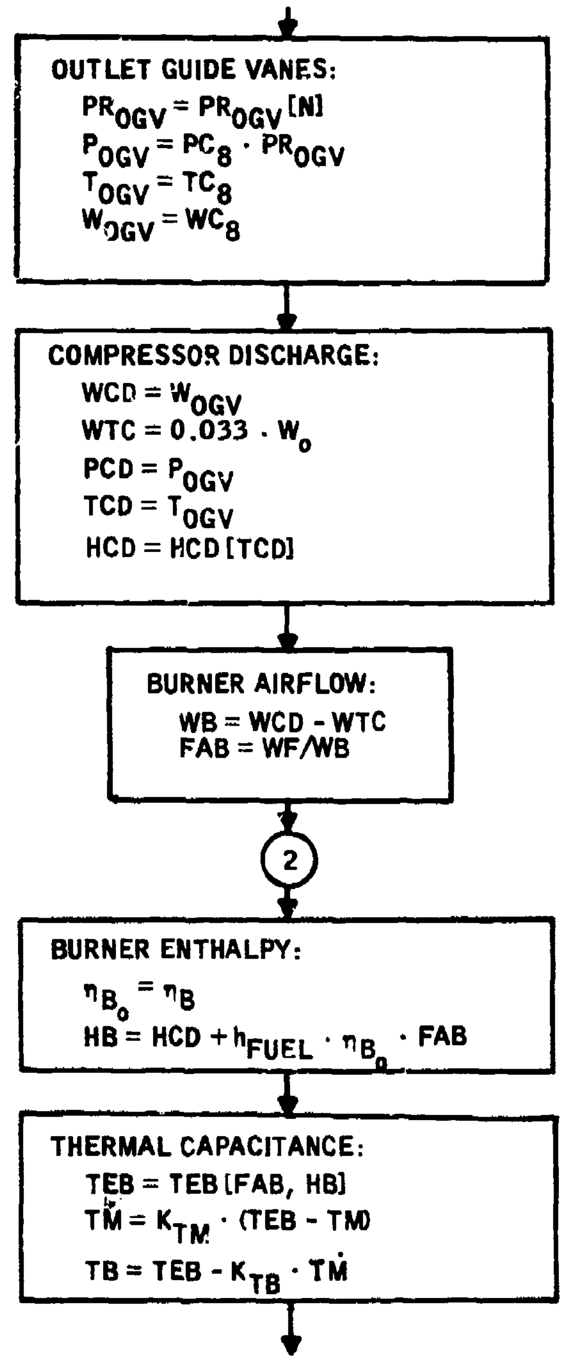


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

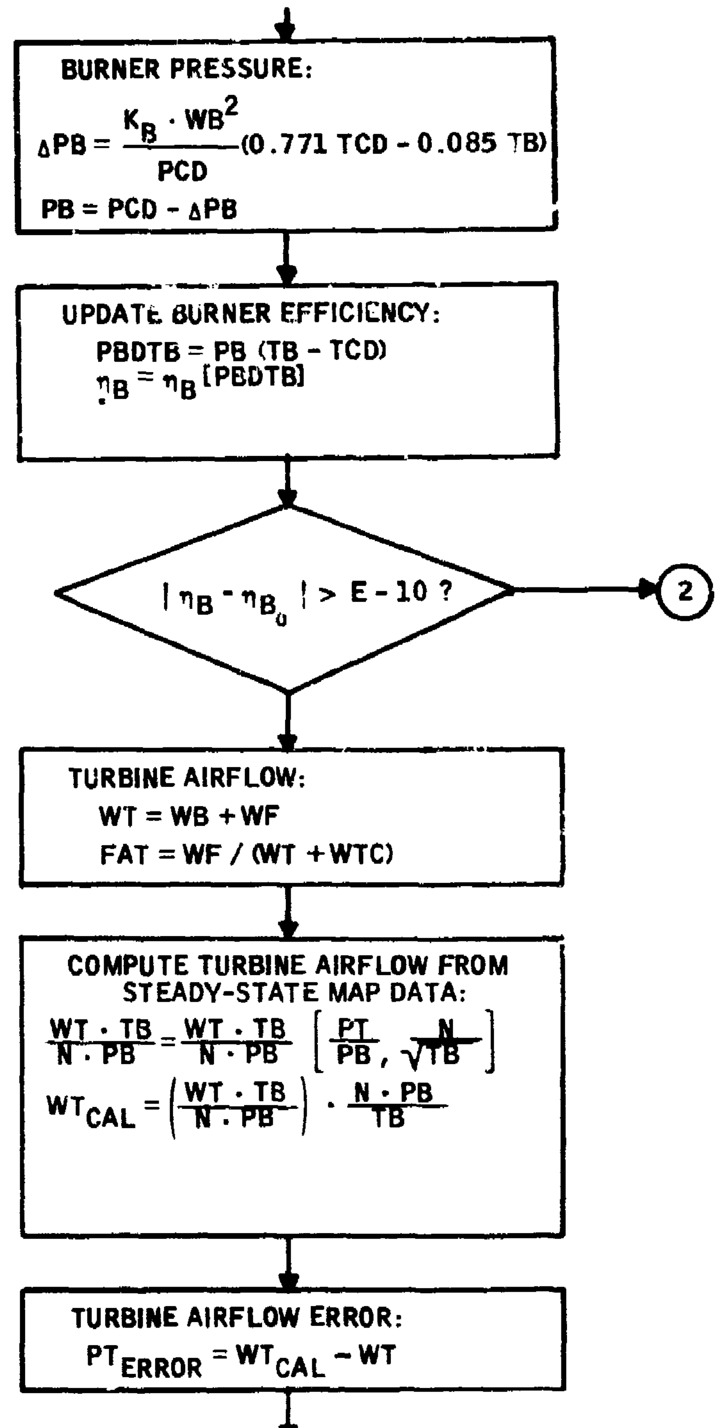


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

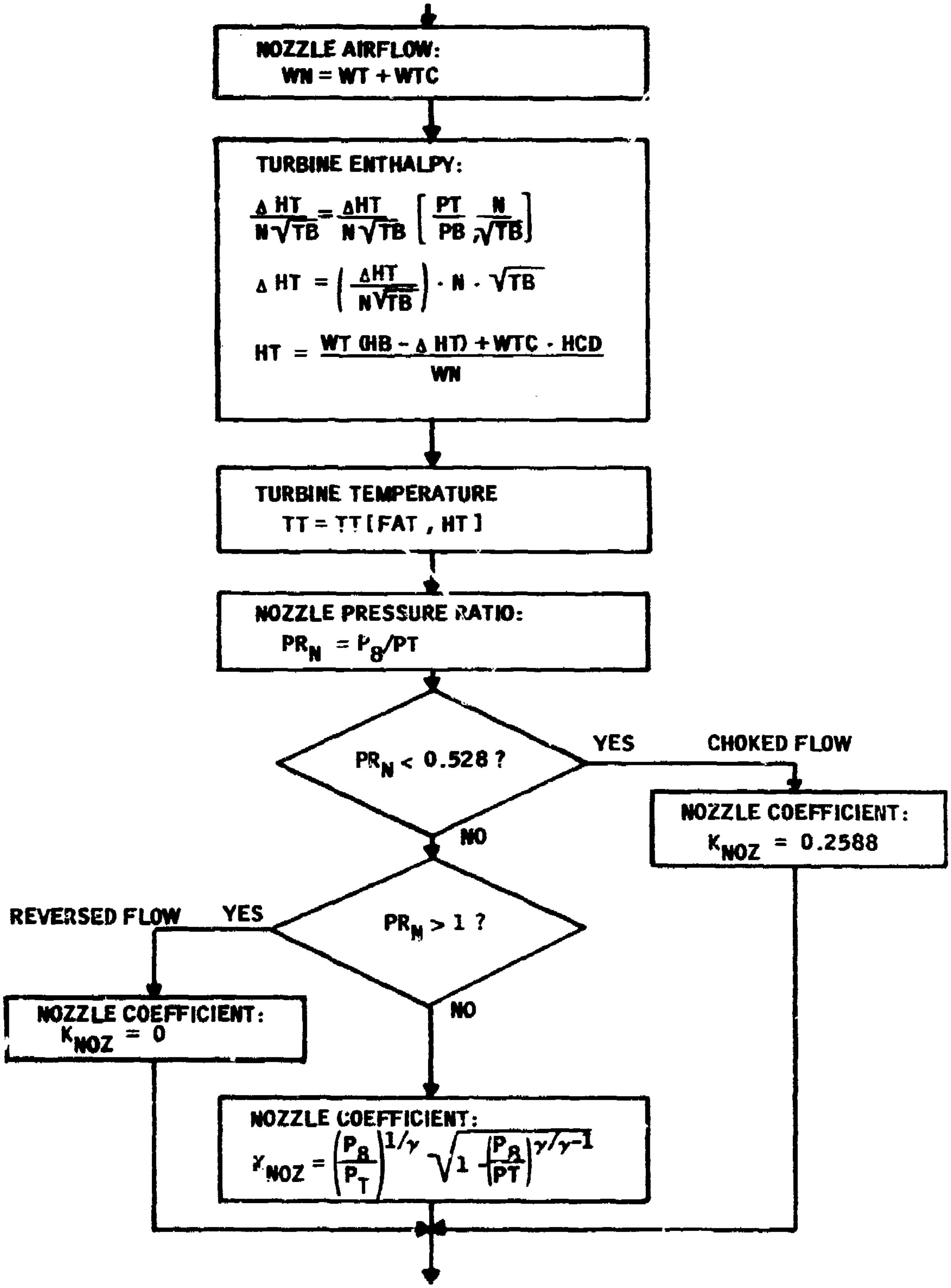


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

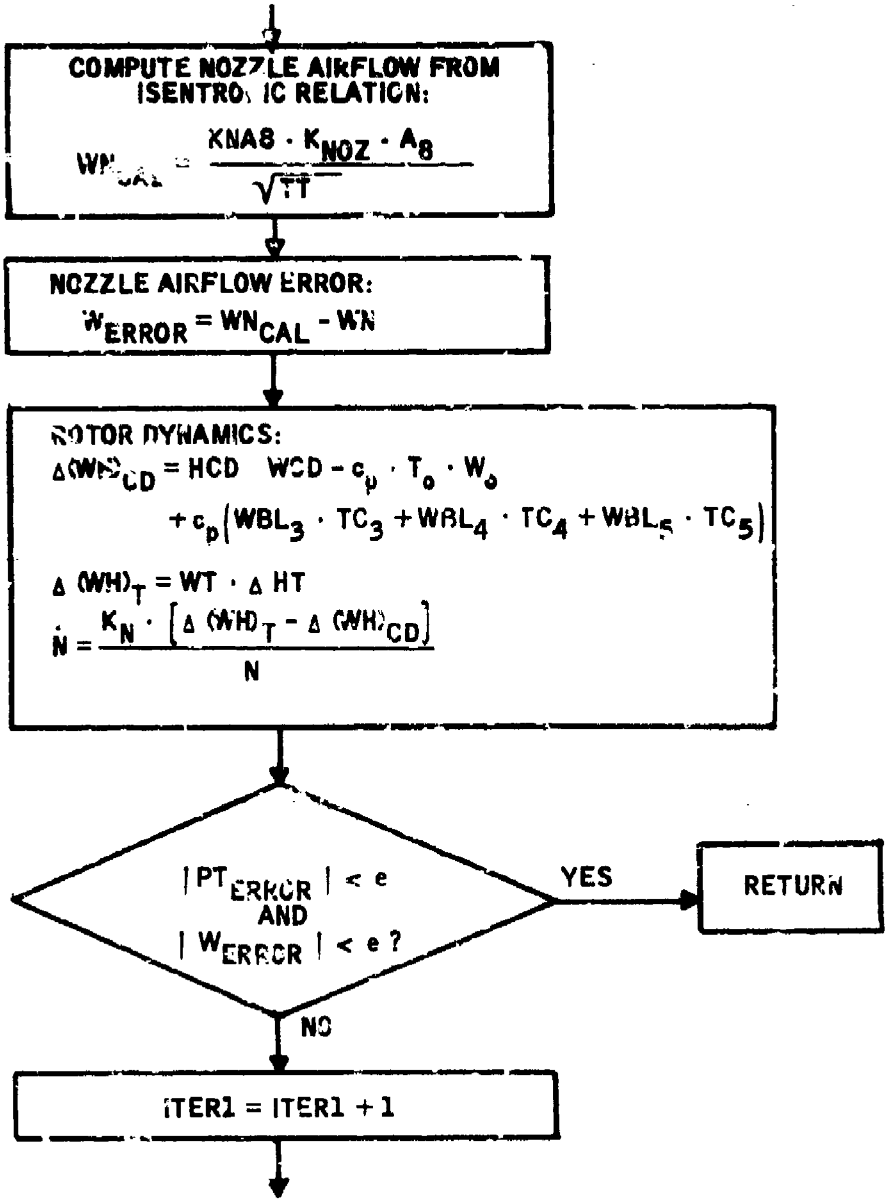


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

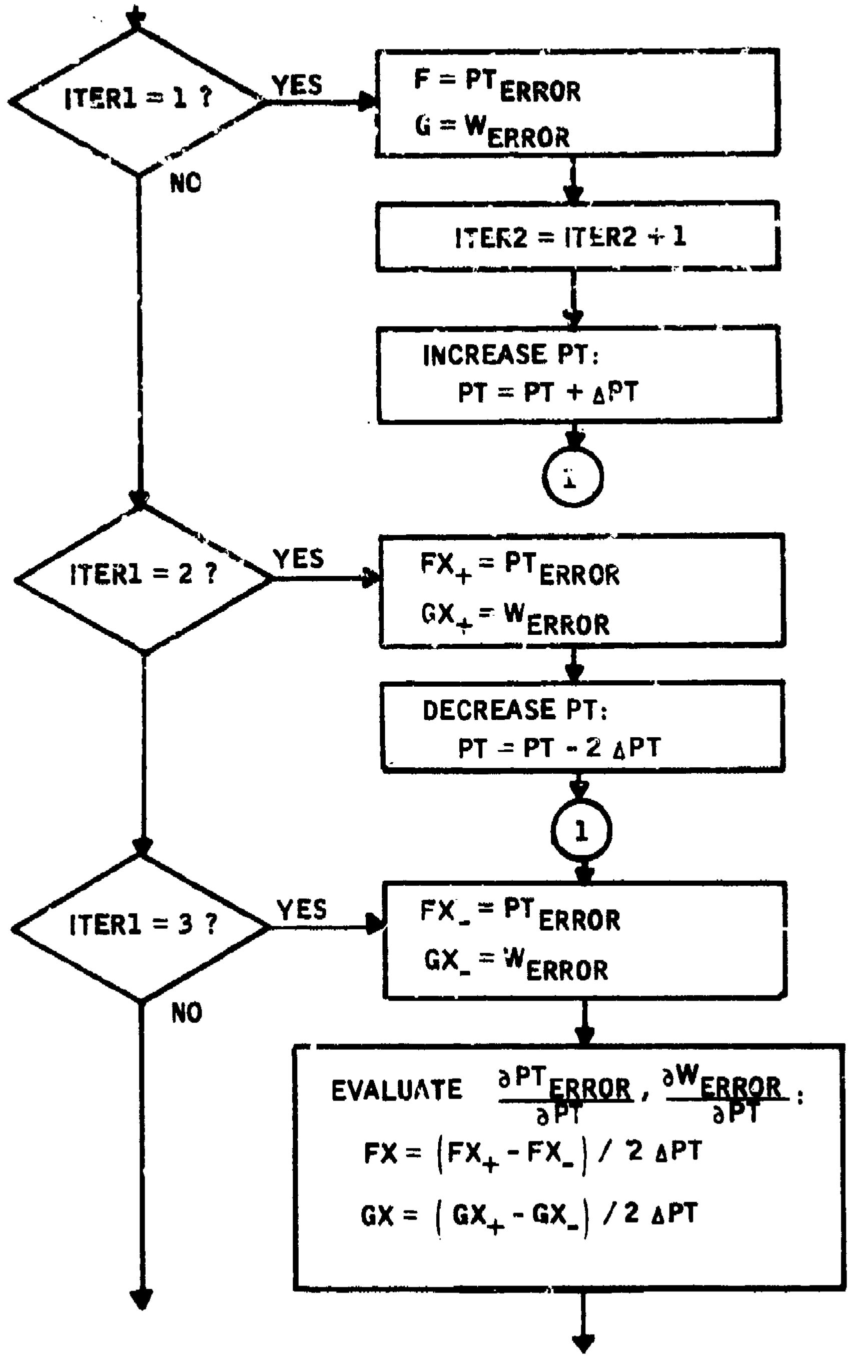


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

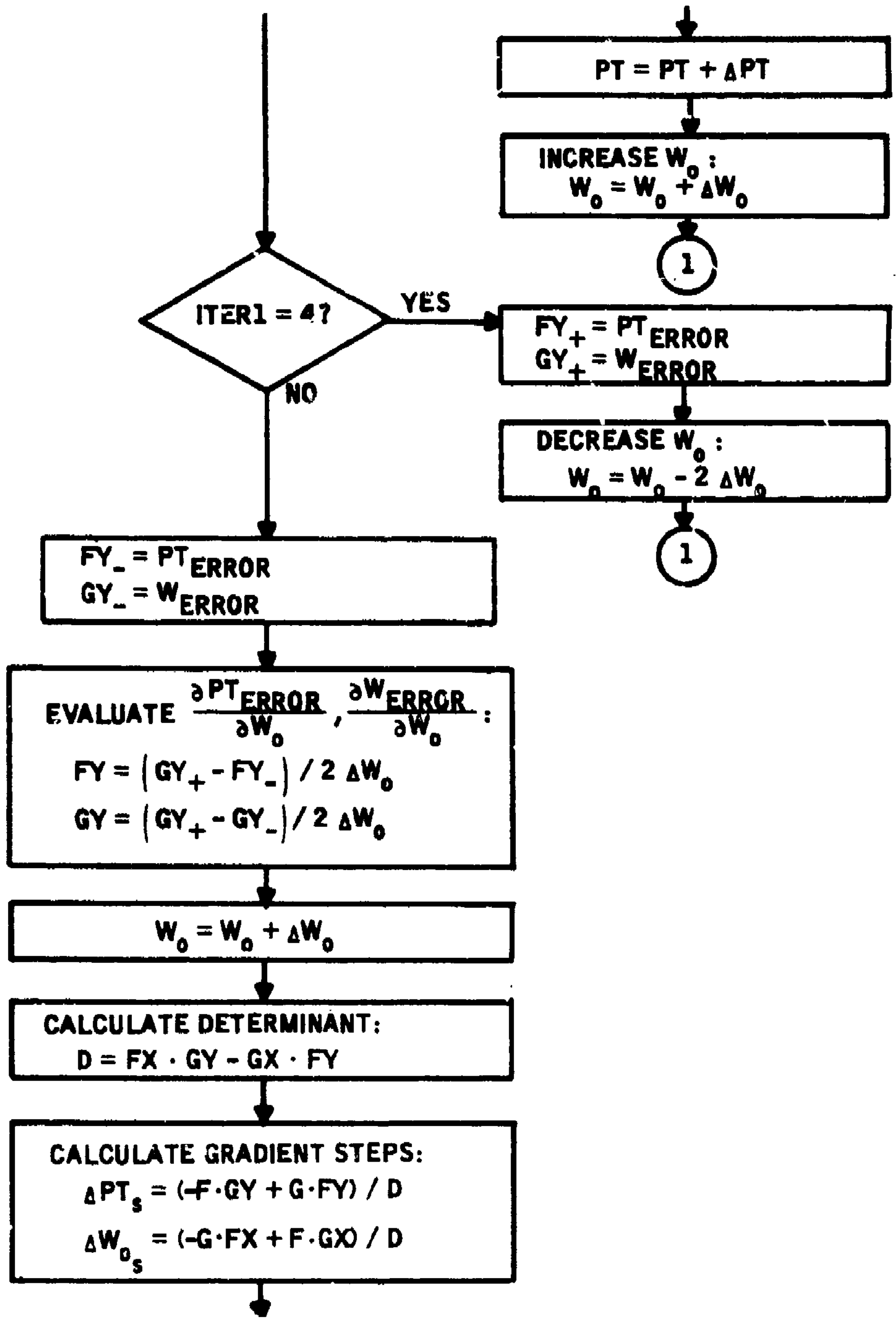


Figure A-2. Subroutine Dynamic Flow Chart (Continued)

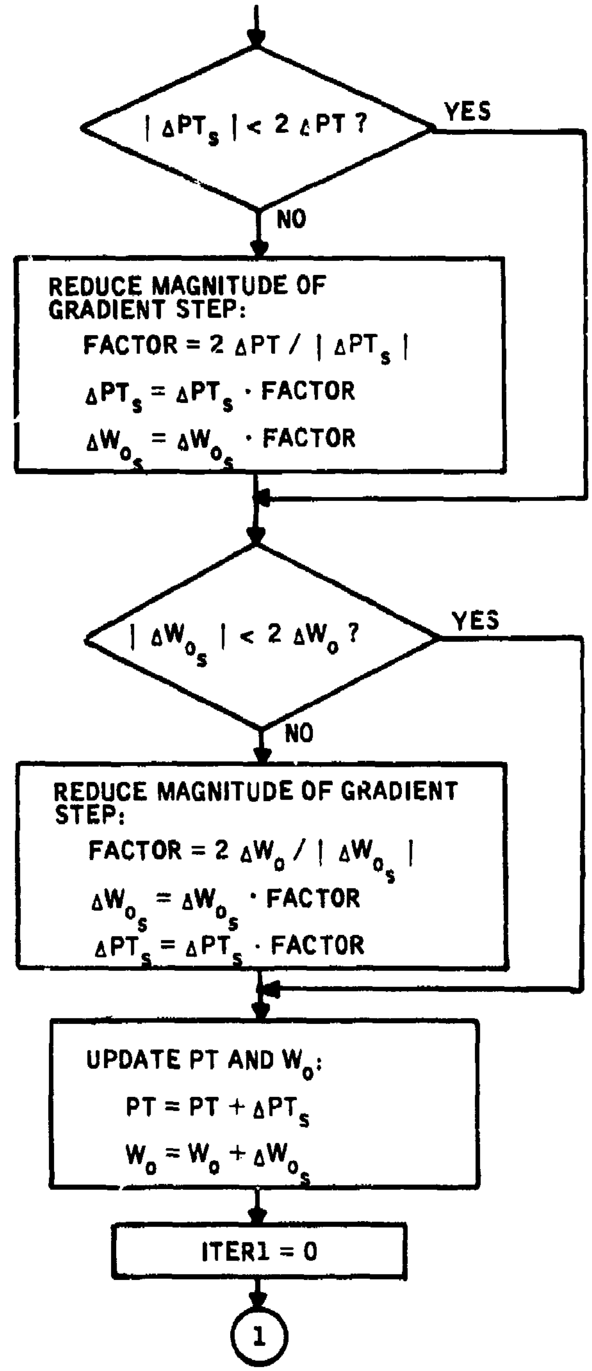


Figure A-2. Subroutine Dynamic Flow Chart (Concluded)

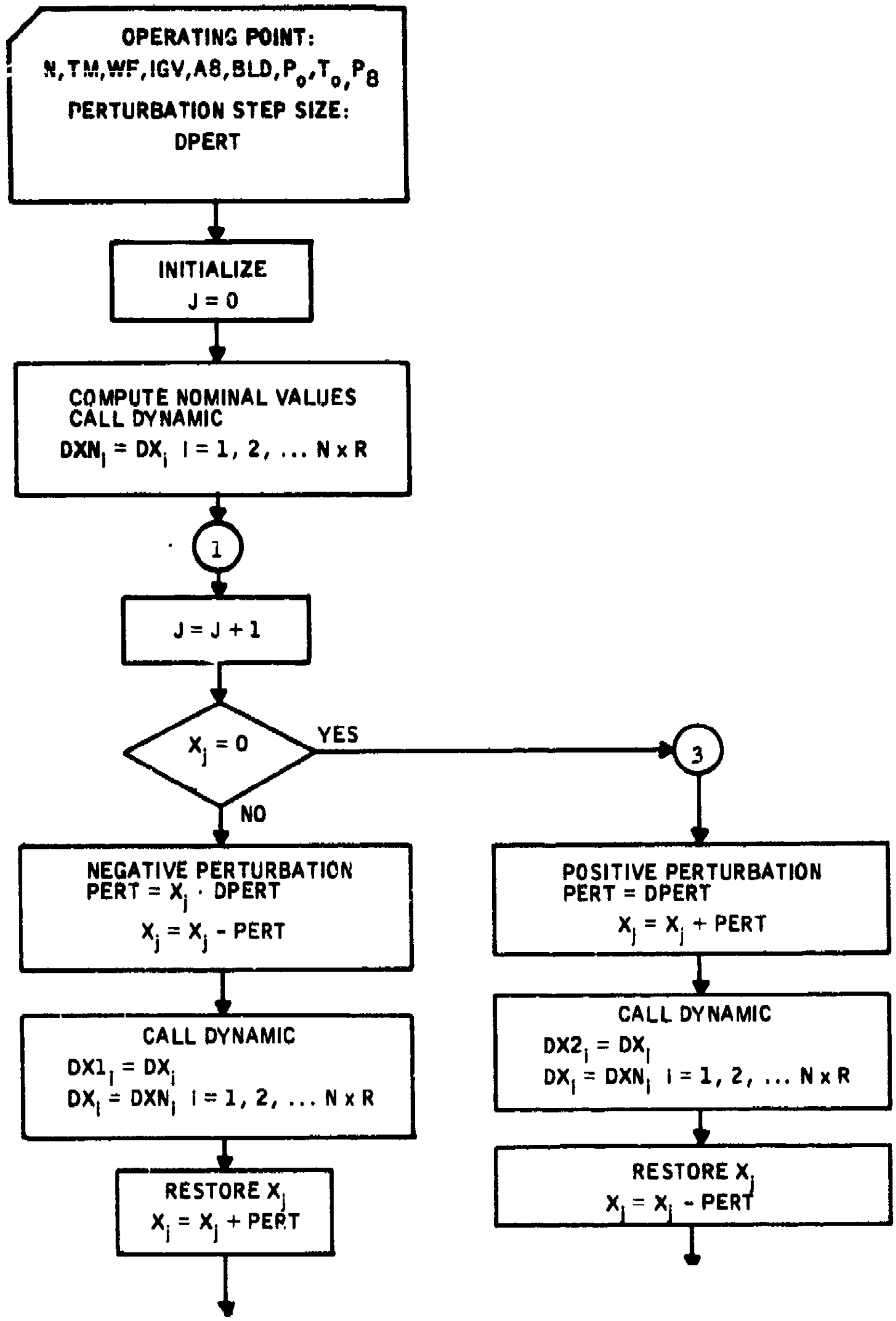


Figure A-3. Linearization Flow Chart

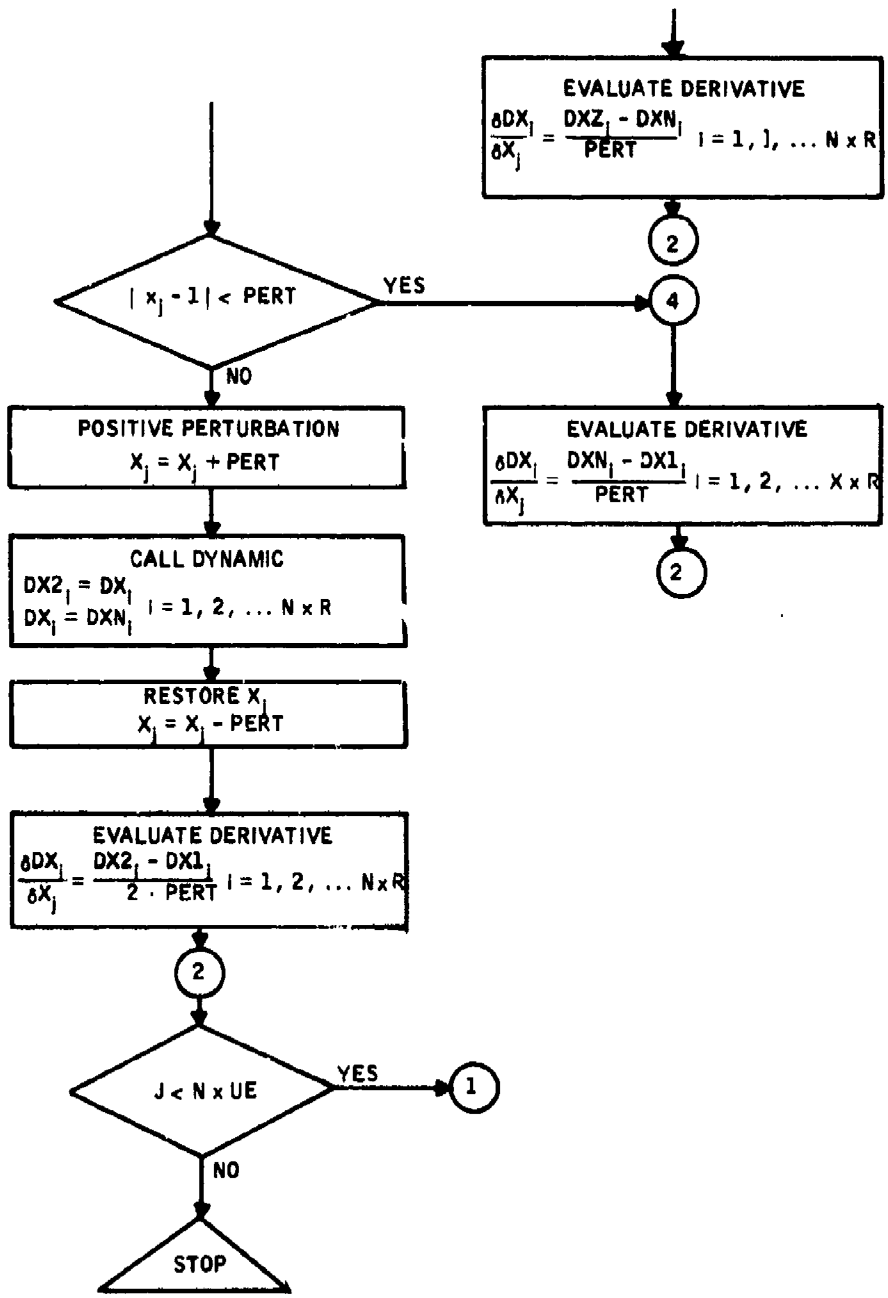


Figure A-3. Linearization Flow Chart (Concluded)

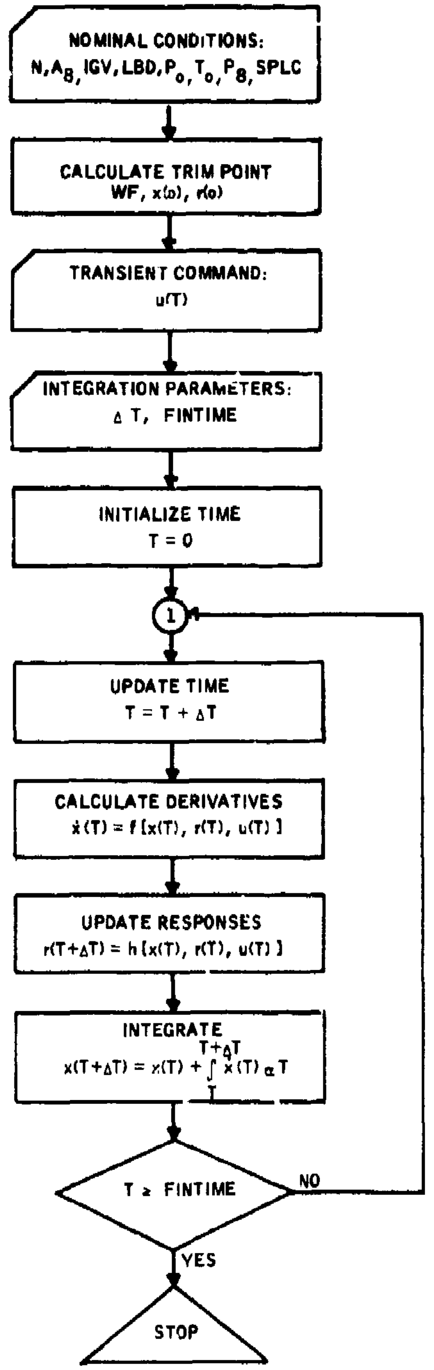


Figure A-4. Nonlinear Engine Simulation Flow Chart

REFERENCES

A-1. Seldner, Kurt, Mihalow, James R., and Blaha, Ronald J., "Generalized Simulation Technique for Turbojet Engine System Analysis," NASA TN D-6610, Lewis Research Center, National Aeronautics and Space Administration, Cleveland, Ohio, February 1972.

A-2. Hsu, Jay C. and Meyer, Andrew V., Modern Control Principles and Applications, McGraw-Hill Book Company, New York, 1960.

APPENDIX B

CONTROLLER SOFTWARE FOR THE APL WIND TUNNEL TEST FACILITY

Software for the optimal command controller synthesized in Section IV (Volume I) is presented. The software is for the IBM 1800 computer at APL. This software inserts the Honeywell optimal controller within the Bendix Bounds program (Reference B-1). The reader is assumed to be familiar with the IBM 1800 (Reference B-2) and with the Bendix Bounds program.

This appendix is divided into three major parts:

- Controller data
- Equilibrium-pressure software
- Equilibrium-temperature software

In the first part of this Appendix, controller data for deceleration-equilibrium-pressure-temperature modes are combined. This system will provide precise speed control and rapid spool speed responses without surge-stall, excessive temperatures, or flameouts. This is close to a control system that we recommend. The adjective close would be deleted by applying standard correction procedures to permit operation at other than the sea level standard design condition.

For expediency, in testing in the APL wind tunnel, the system was divided into two parts:

- Deceleration-equilibrium-pressure
- Deceleration-equilibrium-temperature

The first part does not explicitly provide over-temperature protection while the second does not explicitly provide surge-stall protection. Protection is obtained, however, by setting the pressure limit low enough to prevent over-temperature and the temperature limit low enough to prevent surge-stall.

CONTROLLER DATA

The inlet guide vanes (IGV), bleed (BLD), and exhaust actuator (A8) are operated on open-loop schedules (for reasons discussed in Section IV). Closed-loop control is used on the fuel valve.

For control synthesis the IGV and BLD were set on the G. E. schedule. As Bendix employs the same schedule in the Bounds program, the Bounds schedule for IGV and BLD are used with the Honeywell controllers.

The A8 schedule is the same as that used on a previous Honeywell contract to APL; it is not the bill of materials schedule.

Table B-1 summarizes the open-loop schedules for IGV, BLD, and A8.

Fuel valve command data are presented in Tables B-2 through B-5. Table B-2 presents the generic form for the complete control law.

For deceleration-equilibrium-pressure control ut is deleted from u2 in Equation (3) of Table B-2. For deceleration-equilibrium-temperature control, up is deleted from u2. Feedback gains, open-loop fuel flows, and "equilibrium" data are presented in Tables B-3, B-4, and B-5, respectively.

The equations and data of Tables B-2 through B-5 could have been programmed; a simplification is made before programming. The simplification permits either variable limits (ENL, EPL, or ETL) to be achieved by constants or variable integration parameters to be made constant. For

example, in the $\dot{EP}$ equation (Table B-2) the parameter PC is variable. It can be made constant without changing the resulting control. This is demonstrated by Table B-6. The generic form of the modified state equations and controllers is presented above the dashed line. The integration parameter (d) can be made to take an arbitrary non-zero value by dividing d by μ and by multiplying the integral gain λ by μ; this is shown by the equations below the dashed line.

EQUILIBRIUM-PRESSURE SOFTWARE

Flow charts are presented in Figures B-1 through B-11. Table B-7 contains a glossary of terms. The program is presented in Table B-8.

The main computational blocks of the speed and pressure control program are shown in Figure B-1. A detailed flow chart for each block is subsequently presented.

Initialization

In this section of the program (Figure B-2), all of the gains and open-loop information (i.e., fuels and pressures as a function of speed) are transferred from variable-trim locations. (The variable-trim locations are the sole means of communication between the Honeywell control program and the Bendix Bounds program to the proper locations in the control program.) The labels associated with the variable-trim locations have the prefix VT followed by three digits. There are 254 VT locations. The contents of the first 70 variable-trim locations VT001 - VT070 can be monitored and manually changed from the Bendix interface console. Nominal values of these variables are stored in the Bendix Bounds program in the standard trim locations ST001 - ST070. The section of the Bounds program in which ST001 - ST070 are defined is presented in Table B-9. The contents of locations VT071 - VT254

can only be monitored from console. VT039 acts as a logical switch for the initialization section of the program. If VT039 = 16 this portion of the program will be executed and VT039 will be set to zero. If VT039 $\neq$ 16 the initialization section will be bypassed. Since all the VT numbers encountered in this portion of the program are in the range VT001 - VT070, they can all be manually changed from Bendix interface console.

Interpolation Interval Determination

The gains (associated with the feedback quantities) and the open-loop information (fuel and pressure values) for both the speed controller and the pressure controller are given at four values of speed. To obtain values for the gains and open-loop information over the whole speed regime linear interpolation is used (Figure B-3). Since the quantities to be interpolated are given at four values of speed N, there are three possible intervals of interpolation. The four values of speed are N_1 = 8250 rpm, N_2 = 11,550 rpm, N_3 = 14,025 rpm, and N_4 = 16,500 rpm. Thus, the three intervals are $[N_1, N_2]$, $[N_2, N_3]$, $[N_3, N_4]$. The sensed speed N (in the program sensed speed is VT157) is tested to determine into which interval it falls. Then any quantity, call it f, given at the four values of N can be written as a linear function of N as follows:

$$f(N) = f(N_i)\, C_1 + f(N_{i+1})\, C_2 \tag{B-1}$$

where

$$C_1 = \frac{(N_{i+1} - N)}{(N_{i+1} - N_i)} \quad \text{and} \quad C_2 = \frac{(N - N_i)}{(N_{i+1} - N_i)} \quad \text{for } i = 1, 2, 3.$$

The interval and the quantities C_1 and C_2 are calculated in this portion of the program.

Exits from this section of the program are given the labels IN1F, IN2F or IN3F, depending on whether the sensed speed N satisfies $N_1 \le N \le N_2$, $N_2 \le N \le N_3$, or $N_3 \le N \le N_4$.

Interpolation Logic

The three sections in this portion of the program (Figure B-4) all evaluate an equation like Equation (B-1). Therefore, the logic in each section is the same. The difference is in the label used for $f(N_i)$ and $f(N_{i+1})$. The different labels represent the initial address in a sequence of addresses of quantities associated with the same speed. In each case the label is influenced by index register one (XR1). Initially (XR1) is set to zero and an equation similar to (B-1) is evaluated in double precision. XR1 is then incremented by one and tested against label NGFT (NGFT = 18). If XR1 < NGFT the interpolation continues, if XR1 ≥ NGFT, the interpolation is done and we are transferred to label FUELM.

Interpolation Scaling

Both C_1 and C_2 are numbers such that $0 \le C_1, C_2 \le 1$ and $C_1 + C_2 = 1$. In the IBM 1800, fractional numbers cannot be represented except as the ratio of two integer numbers. Therefore, the computation of C_1 and C_2 has to be scaled. The scale factor used in the program is $2^7 = 128$. The scale factor of 2^7 is removed after the interpolation by a shift right seven.

Integral Speed and Integral Pressure

The integral speed and integral pressure portion of the program (Figure B-5) consists of logic to initialize, integrate, and limit two simple differential equations in time. The integral speed differential equation is

$$\dot{EN} = -5.3333\ (N - N_{PLA}) \tag{B-2}$$

where EN is the integral of the error between sensed speed N(VT157) and requested speed N_{PLA} (VT128).

The integral pressure differential equation is

$$\dot{EP} = -5.3333\ (PT3 - PT33)\ F(N) \tag{B-3}$$

where EP is the integral of the error between sensed PT3 (VT102) and a boundary value PT33 (PT3NB) and F(N) is a function of sensed speed (i.e., the coefficient in the differential equation is not constant; c.f. Table B-6 and the related discussion).

Initialization of the Differential Equations

The initial values of EN and EP are in VT-36 and VT037, respectively. The limiting values of EN and EP are taken to be the absolute values of VT036 and VT037, respectively. The initial value and the limiting value are changed whenever VT039 contains a sixty-four (64) or a sixteen (16).

Integration of the Differential Equations

The differential equations are integrated numerically using the trapezoidal rule

$$X_{n+1} = X_n + \frac{\Delta t}{2}\ (\dot{X}_n + \dot{X}_{n-1}) \tag{B-4}$$

where Δt is 0.015 second, X_n is the current value of the integral, $\dot{X}_n$ is the current value of the derivative, and $\dot{X}_{n-1}$ is the previous value of the derivative.

Interpolation as a Function of Power Lever

Early controllers (not documented) used PT5 and PT3 as well as an open-loop fuel as a function of the power lever (Figure B-7). The speed controllers used in engine tests require only open-loop fuel as a function of power lever. The power lever position is given in terms of a speed request in rpms in VT128. The method of interpolation is the same as it was for sensed speed. However, since only three quantities are being interpolated, no index registers are used.

Fuel Request Calculation

Three fuel requests are calculated: a speed fuel request, a pressure fuel request and a minimum fuel request (Figure B-8). The minimum fuel request is calculated in the interpllation logic as a function of sensed speed and is stored in WFMNN. The speed control fuel request is calculated as the sum of an open-loop fuel scheduled as a linear function of power lever and the following feedback quantities:

- The error between sensed and requested speed
- An integral of the error between sensed and requested speed

The pressure control fuel request is calculated as the sum of an open-loop fuel scheduled as a linear function of sensed speed and the following feedback quantities:

- The error between PT5 sensed and a given PT5 scheduled as a linear function of speed
- The error between P3 sensed and a given P3 scheduled as a linear function of speed
- The integral of the error between P3 sensed and a given P3 as a linear function of speed.

Starting at label MDW6, all of the ingredients used in calculating the fuel request for the speed and pressure controllers are stored in VT162 - VT176 for checking purposes. Beginning at label MEPT, the five feedback quantities mentioned previously are calculated and stored in VT196 - VT200. The speed control fuel request starts at label FREQE and each of the products involved in the sum is stored in VT201 - VT204. Finally, the fuel request for the speed controller is stored in SUMEF and VT071. The pressure fuel request calculation starts at label FREQP and each of the products involved in the sum is stored in VT205 - VT207. The fuel request for the pressure controller is stored in SUMPF and VT072.

Mode Select Logic

In Figure B-9 the mode select logic starts at level MDSWT. The minimum between the speed fuel request VT071 and the pressure fuel request VT072 is stored in VT180. The maximum between VT180 and WFMNN (minimum fuel) is stored in VT180. At this point a mode number is stored in VT074, depending on which controller is used. The mode numbers are: 3276 for the speed controller, 6552 for the pressure controller, and 9828 for the minimum fuel request.

Fuel Request Filter Logic

The fuel request in VT180 is put through a first-order lag [30/(S+30)]. The lag is digitized using Tustin's method with the resulting difference equation

$$y_n = \left(\frac{31}{49}\right) y_{n-1} + \left(\frac{9}{49}\right) U_n + \left(\frac{9}{49}\right) U_{n-1} \qquad \text{(B-5)}$$

where y_n is the current output (i.e., filtered fuel request), y_{n-1} is the previous output, U_n is the current input (unfiltered fuel request) and U_{n-1} is

the previous input. The coefficients in the difference equation are a function of the sample time Δt which is taken to be 0.015 second.

Exhaust Nozzle Request Calculation

Figure B-11 presents the flow chart.

The nozzle is open for speeds less than or equal to 14,025 rpm. The nozzle request representing "open" is stored in VT034. The nozzle is closed for speeds greater than or equal to 16,500 rpm. The nozzle request representing "closed" is stored in VT035. For speeds between 14,025 rpm and 16,500 rpm the nozzle request decreases linearly from "open" to "closed." The "speed" used in the nozzle request calculation is sensed speed (VT157) if the control mode is not speed control. If the control mode is speed control the speed used is that requested by the power lever (VT128). The nozzle request is stored in VT081. After this calculation has been completed and index register one has been restored, one control cycle update has been completed and control is passed to the Bendix program.

EQUILIBRIUM-TEMPERATURE SOFTWARE

Flow charts for the main computational blocks and for each block are presented in Figures B-12 through B-23. Table B-10 is a glossary of terms. The program is presented in Tables B-11 through B-14. A listing of the Bendix Bounds program corresponding to the Equilibrium-Temperature Program is presented in Table B-13.

The main computational blocks for the speed temperature control program are shown in Figure B-12. The major differences between this program and the speed pressure control program are the filtering logic for T4 whistle,

the number of feedbacks, and the names given to the gains and open-loop information. Consequently, a description of each of the blocks in Figure B-12 will be given in comparative terms of the description given for the speed and pressure controller.

Initialization

It is clear from looking at the detached flow chart (Figure B-13) that more items are transferred from variable trim locations to locations in the control program. This is true, because the temperature controller has more feedbacks than the pressure controller. Consequently, the VT numbers encountered in this section of the program are in the range VT001 - VT090 (rather than the previous VT001 - VT070). The Bendix Bounds program has been modified to allow the first 90 VT numbers to be changed at the interface console. Nominal values of these VT variables are stored in the standard trim locations ST001 - ST090 in the beginning of the Bounds program (Table B-13). The logic to get into this section of the program is the same as previously described. In addition to the increased number gains and open-loop information to be transferred, an added logic switch, ISW, is initialized. This switch is used to initialize the filtering logic for T4 whistle.

Interpolation Interval Determination

This section of the program (Figure B-14) is exactly the same as for the speed and pressure control program.

Interpolation Logic

The only differences in this section of the program are the labels (names) given to the gains and open-loop information (fuel, pressures, and temperature) associated with temperature controller as opposed to the pressure controller; cf Figure B-15.

Filtering Logic for T4 Whistle

The temperature sensed by the whistle (VT097) goes through a lead-lag filter and the output of the filter is stored in T4WF, Figure B-16. The transfer function for the filter with VT097 as input and T4WF as output is

$$\frac{T4WF}{VT097} = \frac{\tau_2 S + 1}{(K_1)(\tau_2) S + 1} \tag{B-6}$$

where τ_2 and K_1 are piecewise linear functions of PT3.

The table below gives τ_2 and K_1 versus PT3.

PT3 (psi)	K_1	τ_2
24.5	0.50	30.0
39.0	0.53	17.0
58.5	0.56	10.0
102.0	0.60	8.0

The filter is implemented digitally by the following two equations.

$$\begin{aligned} \dot{X}T4 &= \frac{1}{K_1 \tau_2} (VT097 - XT4) \\ T4WF &= \tau_2 \dot{X}T4 + XT4 \end{aligned} \tag{B-7}$$

In the program, K_1 is scaled up by 100 and τ_2 is scaled up by 10. The label for $K_1 \cdot 100$ is K1THD and the label for $\tau_2 \cdot 10$ is TAU2T. The coding starts at label FUELM with the calculation of K1THD and TAU2T as a function of PG3. At label STP1 the logical switch ISW is tested. If ISW is unequal to 1234, initialization of the filter equations takes place. Otherwise branch to STP2. In the initialization logic $\dot{X}T4$ is set equal to VT097, $\dot{X}T4$ is set equal to zero and ISW is set equal to 1234 followed by a branch to STP3. Starting at label STP2, the derivative $\dot{X}T4$ is calculated double precision and stored in XT4D. At label STP3 the differential equation is integrated one step forward in time using the trapezoidal rule (Δt taken to be 0.015 second). The updated value of XT4 is stored in XT4 in double precision. At this point the filtered T4 whistle is computed and stored in T4WF.

Integral Speed and Integral Temperature

In this portion of the program (Figure B-17) the integral pressure differential equation has been replaced with an integral temperature differential equation

$$\dot{E}T = -13.3333\ (T4WF - T4\partial) \tag{B-8}$$

where ET is the integral of the error between sensed T4 whistle filtered and a boundary value T4 as a function of sensed speed. The initial value of ET is stored in VT038 and the limiting value of ET is taken to be the absolute value of VT033.

Additional logic was added to the integration routine in this section to reset the values of EN and ET to zero under the following conditions:

$$EN = 0 \quad \text{if VT074 (mode switch)} \neq 3276$$

$$ET = 0 \quad \text{if VT074} \neq 6552$$

This logic is inserted in the program immediately after the integrals have been updated (section of the program beginning with statement number HWS03300). The parameters EN and ET are updated only if the program is in the right mode; EN is updated if the speed control loop is regulating the engine and ET is updated if the temperature control loop is regulating the engine.

The rest of this section of the program is the same as described previously.

Interpolation as a Function of Power Lever

This portion of the program (Figure B-19) is exactly the same as previously described for the pressure controller.

Fuel Request Calculation

The pressure fuel request calculation is replaced with a temperature fuel request (Figure B-20). The temperature fuel request is calculated as the sum of an open-loop fuel scheduled as a linear function of sensed speed and the following feedback quantities:

- The error between PT5 sensed and a given PT5 scheduled as a linear function of speed

- The error between PT3 sensed and a given PT3 scheduled as a linear function of speed

- The error between T4 whistle filtered and a T4 given scheduled as a linear function of speed

- The integral of the error between PT3 sensed and a given PT3 scheduled as a linear function of speed.

The temperature fuel request calculation starts at label FREQT and each of the products involved in the sum is stored in VT205 - VT207. The fuel request for the temperature controller is stored in SUMTF and VT073.

Mode Select Logic

The only difference in this section of the program is that the minimum between the speed fuel request VT071 and the temperature fuel request VT073 (rather than the pressure fuel request VT072) is stored in VT180; cf Figure B-21.

Fuel Request Filter Logic

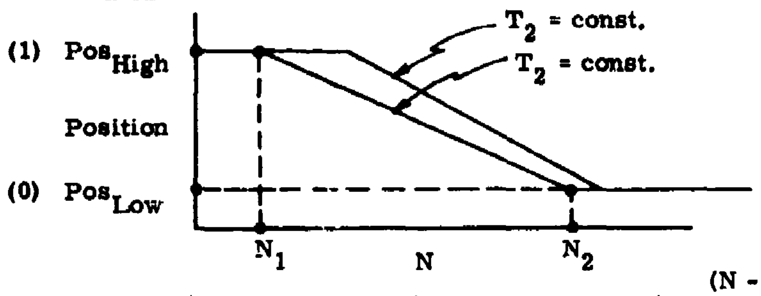
The same as previously described for pressure; Figure B-22.

Exhaust Nozzle Request Calculation

This is the same as previously described for pressure (Figure B-23).

Table B-1. IGV, BLD, and A8 Schedules

IGV and BLD



$$\text{Position} = Pos_{Low} + (Pos_{High} - Pos_{Low}) \times \frac{(N - N_1)}{(N_2 - N_1)}$$

where N is spool speed.

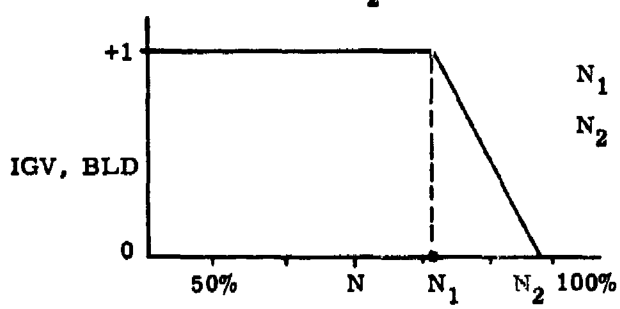
$$N_1\ (\text{rpm}) = 11,800 + (T_2{}^\circ R - 420^\circ R) \times \frac{2100}{160}$$

$$N_2\ (\text{rpm}) = 14,900 + (T_2{}^\circ R - 428^\circ R) \times \frac{1100}{64} \quad \text{if } T_2{}^\circ F \leq 25^\circ F$$

$$= 16,000 - (T_2{}^\circ R - 484^\circ R) \times \frac{200}{50} \quad \text{if } 25^\circ F < T_2{}^\circ F < 75^\circ F$$

$$= 15,800 + (T_2{}^\circ R - 534^\circ R) \times \frac{500}{32} \quad \text{if } T_2{}^\circ F \geq 75^\circ F$$

$\therefore$ on a normal day (T_2 = 70°F) the schedules are:



N_1 = 13,244 rpm, 80.3%

N_2 = 15,816 rpm, 95.8%

A8

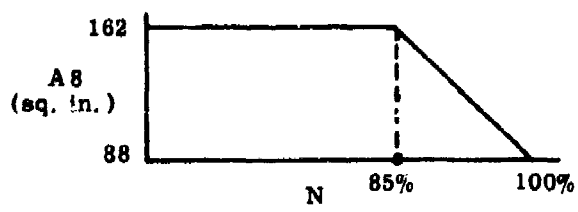


Table B-2. Generic Fuel Control Law

$$u_f = \frac{30.0\,u1}{s + 30.0}$$

$$u1 = \mathrm{Max}\begin{cases} u2 \\ ud \end{cases}$$

$$u2 = \mathrm{Min}\begin{cases} ue \\ up \\ ut \end{cases}$$

$$ud = ud\,[N]$$

$$ue = k_N\,[N - N_o\,(pla)] + k_{EN}\,EN + k_{P3}\,[P3 - P3_o\,(pla)] + k_{PT5}\,[PT5 - PT5_o\,(pla)] + ue_o\,(pla)$$

$$up = k_{EP} + k_{P3}\,[P3 - P3_o\,(N)] + k_{PT5}\,[PT5 - PT5_o(N)] + up_o\,(N)$$

$$ut = k_{ET}ET + k_{TT4}\,[PT5 - PT5_o\,(N)] + ut_o\,(N)$$

$$\dot{EN} = \begin{cases} 0 & \text{If } EN \geq ENL \;\&\; -5.3333\,(N - N_o) \geq 0 \\ 0 & \text{If } EN \leq ENL \;\&\; -5.3333\,(N - N_o) \leq 0 \\ -5.3333\,[N - N_o\,(pla)] & \text{otherwise} \end{cases}$$

$$\dot{EP} = \begin{cases} 0 & \text{If } EP \geq EPL \;\&\; -PC\,(P3 - P3_o) \geq 0 \\ 0 & \text{If } EP \leq EPL \;\&\; -PC\,(P3 - P3_o) \leq 0 \\ -PC(N)\,[P3 - P3_o(N)] & \text{otherwise} \end{cases}$$

Table B-2. Generic Fuel Control Law (Concluded)

where

$$PC = \begin{cases} 5.333 \text{ If } N < 14,025 \text{ rpm} \\ 13.333 \text{ If } N \geq 14,025 \text{ rpm} \end{cases}$$

$$\dot{ET} = \begin{cases} 0 \quad \text{If } ET \geq ETL \ \& \ -13.333\ (T4WF - TT4_o) \geq 0 \\ 0 \quad \text{If } ET \leq ETL \ \& \ -13.333\ (T4WF - TT4_o) \leq 0 \\ -13.333\ [T4WF - TT4_o\ (N)] \text{ otherwise} \end{cases}$$

N (rpm), P3 (psi), and PT5 (psi) are taken to be the outputs of engine sensors, pla is throttle in part of full; e.g., 0.75 pla commands 75 percent rpm, T4W (°R) is the output of the Honeywell fluidic (whistle) T4 sensor

$$T4WF = \left[\frac{1}{(KI)\tau 2} \left(1 - \frac{1}{KI}\right) (P3)\right] T4DUM + \frac{1}{KI} (P3)\ TT4W$$

$$T4DUM = \left[\frac{1}{(KI)\ (T2)} (P3)\right] T4DUM + TT4W$$

$$T4WF \approx \frac{50.0}{S + 50}\ TT4$$

$$ENL = 200.0$$

$$EPL = 1.0$$

$$ETL = 100.0$$

Table B-3. Perturbation Gains

% N	k_N (lb/sec)/rpm	k_E N P T	k_{P3} (lb/sec)/psi	k_{PT5} (lb/sec)/psi	k_{TT4} (lb/sec)/(deg F)
50E	-0.46718-3	+0.58461-4	---	---	---
50P	---	+0.45650-1	-0.18636+0	+0.15861+0	---
50T	---	+0.11304-3	-0.15966-2	+0.12096-2	-0.22757-3
70E	-0.27136-3	+0.53844-4	---	---	---
70P	---	+0.20271-1	-0.62334-1	-0.44936-1	---
70T	---	+0.14074-3	+0.53354-1	-0.20311-2	-0.28462-3
85E	-0.26479-3	+0.12239-3	---	---	---
85P	---	+0.15561-2	-0.71783-1	+0.51485-1	---
85T	---	+0.16155-3	+0.91896-2	-0.74486-3	-0.18812-3
100E	-0.53363-3	+0.31975-3	---	---	---
100P	---	+0.12779-1	-0.49166-1	+0.43431-1	---
100T	---	+0.23413-3	-0.18094-1	+0.13297-1	-0.78669-5

Table B-4. Open-Loop Fuel Flows* (lb/hr)

% N	ue_o[pla]	up_o[N]	ut_o[N]	ud[N]
50.0	519.0	779.0	651.0	200.0
70.0	693.0	1740.0	1000.0	350.0
85.0	934.0	2573.0	2000.0	500.0
100.0	1648.0	3478.0	2400.0	1000.0

* These are for the APL engine at 29.55 inches of Hg and 82°F.
They should be corrected with ambient conditions.

Table B-5. Equilibrium and Boundary States*

%N	50	70	85	100
Equilibrium				
N_o[pla]rpm	8,250.0	11,550.0	14,025.0	16,500.0
Pressure				
$P3_o$[N]psi	22.0	35.5	55.0	80.0
$PT5_o$[N]psi	14.8	16.4	20.5	25.6
Temperature				
$TT4_o$[N]°F	1,020.0	900.0	1,050.0	1,160.0
$P3_o$[N]psi	23.5	35.5	55.0	80.0
$PT5_o$[N]psi	14.8	16.4	20.5	26.5

*These are for the APL engine at 99.99 inches of Hg and 99°F. They should be corrected with ambient conditions.

Table B-6. An Integral Transformation

$$
\begin{aligned}
\dot{x} &= +Fx \\
\dot{E} &= -dx \\
\dot{w}_f &= +Fx \qquad\qquad - a\,w_f + gu \\
u &= +kx
\end{aligned}
$$

- -

$$
\begin{aligned}
\dot{x} &= +Fx \\
\frac{\dot{E}}{\mu} &= -\frac{d}{\mu}\,x \\
\dot{w}_f &= \qquad\qquad\qquad - a\,w_f + gu \\
u &= +kx + (\lambda\mu)\frac{E}{\mu}
\end{aligned}
$$

Table B-7. Glossary for Equilibrium - Pressure Control

VT Number	Transferred To (Program Label)	Description	Standard Value (Defined in the Bendix Program)
009	---	Logic switch: If VT009 > 123 the Honeywell controller is in; otherwise not	0
012	DEF11	Speed control gain associated with $(N-N_{pla})$ at 8250 rpm	(-215) x 16
013	WEF1	Open-loop fuel-speed control at 8250 rpm	519 lb/hr
014	P3P1	Open-loop PT3-speed control at 8250 rpm	2200 (psi x 100)
015	KEF14	Speed control gain associated with EN at 8250 rpm	(27) x 16
016	KEF21	Speed control gain associated with $(N-N_{pla})$ at 11, 550 rpm	(-126) x 16
017	WEF2	Open-loop fuel-speed control at 11,550 rpm	693 lb/hr
018	P3P2	Open-loop PT3 - speed control at 11,550 rpm	3550 (psi x 100)
019	KEF24	Speed control gain associated with EN at 11,550 rpm	(25) x 16
020	KEF31	Speed control gain associated with $(N-N_{pla})$ at 14,025 rpm	(-122) x 16
021	WEF3	Open-loop fuel-speed control at 14,025 rpm	934 lb/hr
022	P3P3	Open-loop PT_3 - speed control at 14,025 rpm	5500 (psi) x 100
023	KEF34	Speed control gain associated with EN at 14,025 rpm	(56) x 16
026	---	If this number is made large, Bendix bound on fuel will not be in effect	2^{14}
028	---	Logical switch: if VT028 = 64 Honeywell nozzle is used; otherwise not	0

Table B-7. Glossary for Equilibrium - Pressure Control (Continued)

VT Number	Transferred To (Program Label)	Description	Standard Value (Defined in the Bendix Program)
034	---	Exhaust request open	9640
035	---	Exhaust request closed	2650
036	ENK, ENKL	Initial value of integral speed limits value	1600
037	EPK, EPKL	Initial value of integral pressure limits value	1600
039	---	Logic switch: VT039 = 16 initializes everything. VT039=64 initializes EN, EP only	16
040	KEF41	Speed control gain associated with ($N-N_{pla}$) at 16,500 rpm	(-246) x 16
041	WEF4	Open-loop fuel-speed control at 16,500 rpm	1648 lb/hr
042	P3P4	Open-loop PT3 - speed control at 16,500 rpm	0090 (psi x 100)
043	KEF44	Speed control gain associated with EN at 16,500 rpm	(147) x 16
044	KPF11	Fudge factor used in EP at 8250 rpm	3089
045	KPF12	Pressure control gain - (PT5 - PT5∂) at 8250 rpm	(571) x 16
046	KPF13	Pressure control gain - (PT3 - PT3∂) at 8250 rpm	(-671) x 16
047	WPF1	Open-loop fuel-pressure control at 8250 rpm	779 lb/hr
048	KPF21	Fudge factor used in EP at 11,550 rpm	(576) x 16
049	KPF22	Pressure control gain - (PT5 - PT5∂) at 11,550 rpm	(-162) x 16
050	KPF23	Pressure control gain - (PT3 - PT3∂) at 11,550 rpm	(-224) x 16

Table B-7. Glossary for Equilibrium - Pressure Control (Concluded)

VT Number	Transferred To (Program Label)	Description	Standard Value (Defined in the Bendix Program)
061	WPF2	Open-loop fuel-pressure control at 11,550 rpm	1740 lb/hr
062	KPF31	Fudge factor used in EP at 14,025 rpm	(59) x 16
063	KPF32	Pressure control gain - (PT5 - PT5a) at 14,025 rpm	(185) x 16
064	KPF33	Pressure control gain - (PT3 - PT3a) at 14,025 rpm	(-258) x 16
065	WPF3	Open-loop fuel-pressure control at 14,025 rpm	2573 lb/hr
066	KPF41	Fudge factor used in EP at 16,500 rpm	(364) x 16
067	KPF42	Pressure control gain - (PT5 - PT5a) at 16,500 rpm	(156) x 16
068	KPF43	Pressure control gain (PT3 - PT3a) at 16,500 rpm	(-177) x 16
069	WPF4	Open-loop fuel-pressure control at 16,500 rpm	3478 lb/hr
071	---	Speed fuel request 1 count = 4 lb/hr	0
072	---	Pressure fuel request 1 count = 4 lb/hr	0
074	---	Mode number 3276 = speed control 6552 = pressure control 9228 = minimum fuel	0
081	--	Exhaust actuator request	0
180	---	Fuel request calculated by control program 3.25 counts = 1 lb/hr	---

Table B-8. Equilibrium - Pressure Subprogram

```
// JOB         VDISK
// DMP
*DELETE                HWECT
// ASM                                                                    HWS00010
*OVERFLOW SECTORS ,,,9                                                    HWS00020
*LIST                                                                     HWS00030
*XREF                                                                     HWS00040
*ONEWORDINTEGERS                                                          HWS00050
*COMMON IDUMY(127),IVT00,JDUMY(127),ISTO,MEAST(64),IASCW(8)              HWS00060
                      ENT       HWECT                                     HWS00070
                HWECT DC        ***                                       HWS00080
                      STX   L1  XR1+1                                     HWS00090
                *                                                         HWS00100
                      LDX   L1  0                                         HWS00110
                      B     L   TESTN                                     HWS00120
                *
                *   INITIALIZATION
                *
                TESTN EQU       *                                         HWS00190
                      LD     2  VT039
                      S     L   *16
                      BNZ       MICK
                      STO    2  VT039
                      LD     2  VT012
                      SRT       4
                      STO   L   KEF11
                      LD     2  VT013
                      STO   L   WEF1
                      LD     2  VT014
                      STO   L   P3P1
                      LD     2  VT015
                      SRT       4
                      STO   L   KEF14
                      LD     2  VT016
                      SRT       4
                      STO   L   KEF21
                      LD     2  VT017
                      STO   L   WEF2
                      LD     2  VT018
                      STO   L   P3P2
                      LD     2  VT019
                      SRT       4
                      STO   L   KEF24
                      LD     2  VT020
                      SRT       4
                      STO   L   KEF31
                      LD     2  VT021
                      STO   L   WEF3
                      LD     2  VT022
                      STO   L   P3P3
                      LD     2  VT023
                      SRT       4
                      STO   L   KEF34
                      LD     2  VT040
                      SRT       4
                      STO   L   KEF41
                      LD     2  VT041
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
         STO   L   WEF4
         LD      2 VT042
         STO   L   P3P4
         LD      2 VT043
         SRT       4
         STO   L   KEF44
         LD      2 VT044
         STO   L   KPF11
         LD      2 VT045
         SRT       4
         STO   L   KPF12
         LD      2 VT046
         SRT       4
         STO   L   KPF13
         LD      2 VT047
         STO   L   WPF1
         LD      2 VT048
         SRT       4
         STO   L   KPF21
         LD      2 VT049
         SRT       4
         STO   L   KPF22
         LD      2 VT050
         SRT       4
         STO   L   KPF23
         LD      2 VT061
         STO   L   WPF2
         LD      2 VT062
         SRT       4
         STO   L   KPF31
         LD      2 VT063
         SRT       4
         STO   L   KPF32
         LD      2 VT064
         SRT       4
         STO   L   KPF33
         LD      2 VT065
         STO   L   WPF3
         LD      2 VT066
         SRT       4
         STO   L   KPF41
         LD      2 VT067
         SRT       4
         STO   L   KPF42
         LD      2 VT068
         SRT       4
         STO   L   KPF43
         LD      2 VT069
         STO   L   WPF4
         LD    L   *0
         STO   L   TIME
         STO   L   SWLAG
*                                                              HWS00160
*INTERVAL DETERMINATION                                        HWS00170
*                                                              HWS00180
MICK     EQU       *
         LD      2 VT157                                       HWS00200
         S         *6250                                       HWS00210
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
         BP        TMAX                                  HWS00220
         LD        =1                                    HWS00230
         STO       NIN                                   HWS00240
         LD        =128
         STO       C1                                    HWS00260
         LD        =0                                    HWS00270
         STO       C2                                    HWS00280
         B     L   IN1F                                  HWS00290
C1       DC        *-*                                   HWS00130
C2       DC        *-*                                   HWS00140
NIN      DC        *-*                                   HWS00150
         LORG
TMAX     LD        =16500                                HWS00300
         S       2 VT157                                 HWS00310
         BP        TIN1                                  HWS00320
         LD        =3                                    HWS00330
         STO       NIN                                   HWS00340
         LD        =0                                    HWS00350
         STO       C1                                    HWS00360
         LD        =128
         STO       C2                                    HWS00380
         B     L   IN3F                                  HWS00390
TIN1     LD        =11550                                HWS00400
         S       2 VT157                                 HWS00410
         BN        TIN2                                  HWS00420
         SRT       9
         D         =3300                                 HWS00440
         STO       C1                                    HWS00450
         LD        =128
         S         C1                                    HWS00470
         STO       C2                                    HWS00480
         LD        =1                                    HWS00490
         STO       NIN                                   HWS00500
         B     L   IN1F                                  HWS00510
TIN2     LD        =14025                                HWS00520
         S       2 VT157                                 HWS00530
         BN        TIN3                                  HWS00540
         SRT       9
         D         =2475                                 HWS00560
         STO       C1                                    HWS00570
         LD        =128
         S         C1                                    HWS00590
         STO       C2                                    HWS00600
         LD        =2                                    HWS00610
         STO       NIN                                   HWS00620
         B     L   IN2F                                  HWS00630
TIN3     LD        =16500                                HWS00640
         S       2 VT157                                 HWS00650
         SRT       9
         D         =2475                                 HWS00670
         STO       C1                                    HWS00680
         LD        =128
         S         C1                                    HWS00700
         STO       C2                                    HWS00710
         LD        =3                                    HWS00720
         STO       NIN                                   HWS00730
         B     L   IN3F                                  HWS00740
         LORG                                            HWS00750
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
*         EQUILIBRIUM FUEL FLOW 50 GAINS                  HWS00760
KEF11  DC       ***
KEF12  DC       0
KEF13  DC       0
KEF14  DC       ***
WEF1   DC       ***
P3E1   DC       2705
P5E1   DC       1633
*         PRESSURE   FUEL FLOW 50 GAINS                   HWS00840
KPF11  DC       ***
KPF12  DC       ***
KPF13  DC       ***
KPF14  DC       63
WPF1   DC       ***
P3P1   DC       ***
P5P1   DC       1480
WTF1   DC       1118                                      HWS00930
A61    DC       162                                       HWS00940
WFMN1  DC       650
T61    DC       2602                                      HWS00970
BUMP1  DC       1                                         HWS00980
SETX1  DC       0                                         HWS00990
NGFT   DC       18
C11    DC       ***                                       HWS01010
C21    DC       ***                                       HWS01020
TST1   DC       ***                                       HWS01040
SUM1   BSS   E  0
       DC       0
       DC       0
*
*  INTERPOLATE INTERVAL 1
*
IN1F   EQU      *                                         HWS01050
       LD    L  C1                                        HWS01060
       STO      C11                                       HWS01070
       LD    L  C2                                        HWS01080
       STO      C21                                       HWS01090
       LD    L  SETX1                                     HWS01100
       STO      TST1                                      HWS01110
LUP1   LDX   I1 TST1                                      HWS01120
       LD    L1 KEF11                                     HWS01130
       M        C11                                       HWS01140
       STD      SUM1
       LD    L1 KEF21                                     HWS01170
       M        C21                                       HWS01180
       AD       SUM1
       SRT      7
       SLT      16
       STO   L1 KEFN1                                     HWS01220
       LD       TST1                                      HWS01230
       A     L  BUMP1                                     HWS01240
       STO      TST1                                      HWS01250
       S     L  NGFT                                      HWS01260
       BN       LUP1                                      HWS01270
       B     L  FUFLM                                     HWS01280
*         EQUILIBRIUM FUEL FLOW 70 GAINS                  HWS01290
KEF21  DC       ***
KEF22  DC       0
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
KEF23 DC       0
KEF24 DC       ***
WEF2  DC       ***
P3E2  DC       4361
P5E2  DC       1893
*       PRESSURE    FUEL FLOW 70 GAINS                    HWS01370
KPF21 DC       ***
KPF22 DC       ***
KPF23 DC       ***
KPF24 DC       127
WPF2  DC       ***
P3P2  DC       ***
P5P2  DC       1640
WTF2  DC       1877                                       HWS01460
AB2   DC       162                                        HWS01470
WFMN2 DC       1138
TB2   DC       2563                                       HWS01500
C12   DC       ***                                        HWS01510
C22   DC       ***                                        HWS01520
TST2  DC       ***                                        HWS01540
SUM2  BSS   E  0
      DC       0
      DC       0
*
*   INTERPOLATE INTERVAL 2
*
IN2F  EQU      *                                          HWS01550
      LD    L  C1                                         HWS01560
      STO      C12                                        HWS01570
      LD    L  C2                                         HWS01580
      STO      C22                                        HWS01590
      LD    L  SETX1                                      HWS01600
      STO      TST2                                       HWS01610
LUP2  LDX   I1 TST2                                       HWS01620
      LD    L1 KEF21                                      HWS01630
      M        C12                                        HWS01640
      STD      SUM2
      LD    L1 KEF31                                      HWS01670
      M        C22                                        HWS01680
      AD       SUM2
      SRT      7
      SLT      16
      STO   L1 KEFN1                                      HWS01720
      LD       TST2                                       HWS01730
      A     L  BUMP1                                      HWS01740
      STO      TST2                                       HWS01750
      S     L  NGFT                                       HWS01760
      BN       LUP2                                       HWS01770
      B     L  FUELM                                      HWS01780
*       EQUILIBRIUM FUEL FLOW 85 GAINS                    HWS01790
KEF31 DC       ***
KEF32 DC       0
KEF33 DC       0
KEF34 DC       ***
WEF3  DC       ***
P3E3  DC       6161
P5E3  DC       2243
*       PRESSURE    FUEL FLOW 85 GAINS                    HWS01870
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
KPF31 DC        ***
KPF32 DC        ***
KPF33 DC        ***
KPF34 DC        236
WPF3  DC        ***
P3P3  DC        ***
P5P3  DC        2050
WTF3  DC        3102                                  HWS01960
AB3   DC        162                                   HWS01970
WFMN3 DC        1625
TB3   DC        2743                                  HWS02000
C13   DC        ***                                   HWS02010
C23   DC        ***                                   HWS02020
TST3  DC        ***                                   HWS02040
SUM3  BSS   E   0
      DC        0
      DC        0
*
*  INTERPOLATE INTERVAL 3
*
IN3F  EQU       *                                     HWS02050
      LD    L   C1                                    HWS02060
      STO       C13                                   HWS02070
      LD    L   C2                                    HWS02080
      STO       C23                                   HWS02090
      LD    L   SETX1                                 HWS02100
      STO       TST3                                  HWS02110
LUP3  LDX   I1  TST3                                  HWS02120
      LD    L1  KEF31                                 HWS02130
      M         C13                                   HWS02140
      STD       SUM3
      LD    L1  KEF41                                 HWS02170
      M         C23                                   HWS02180
      AD        SUM3
      SRT       7
      SLT       16
      STO   L1  KEFN1                                 HWS02220
      LD        TST3                                  HWS02230
      A     L   BUMP1                                 HWS02240
      STO       TST3                                  HWS02250
      S     L   NGFT                                  HWS02260
      BN        LUP3                                  HWS02270
      B     L   FUELM                                 HWS02280
*          EQUILIBRIUM FUEL FLOW 100 GAINS            HWS02290
KEF41 DC        ***
KEF42 DC        0
KEF43 DC        0
KEF44 DC        ***
WEF4  DC        ***
P3E4  DC        10110
P5E4  DC        3988
*          PRESSURE FUEL FLOW 100 GAINS               HWS02370
KPF41 DC        ***
KPF42 DC        ***
KPF43 DC        ***
KPF44 DC        317
WPF4  DC        ***
P3P4  DC        ***
P5P4  DC        2650
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
        DC        91
ARMAX   DC        3250
T84     DC        2684                                    HWS02500
FUELM   EQU       *                                       HWS02510
*
*  INITIALIZE INTEGRALS AND LIMITS ON INTEGRALS
*
        LD     2  VT039                                   HWS02520
        S         *64                                     HWS02530
        BNZ       MOW9                                    HWS02540
        STO    2  VT039
        LD     2  VT036                                   HWS02550
        STO       ENK
        BNN       SENL
        LD        *0
        S         ENK
SENL    STO       ENKL
        LD     2  VT037                                   HWS02570
        SRT       4
        STO       EPK
        BNN       SEPL
        LD        *0
        S         EPK
SEPL    STO       EPKL
        LD     2  VT038                                   HWS02590
        STO       ETKL                                    HWS02600
        STO       ETK
MOW9    EQU       *                                       HWS02610
*                                                         HWS02620
*                                                         HWS02630
*                                                         HWS02720
*  CALCULATE DERIVATIVES FOR EN EP ET                     HWS02730
*                                                         HWS02740
        LD     2  VT158                                   HWS02750
        S      2  VT157                                   HWS02760
        STO       ENDK                                    HWS02770
        LD     L  PT3NB                                   HWS02820
        S      2  VT102
        STO       EPDK                                    HWS02840
        LD     2  VT097                                   HWS02850
        SRT       16                                      HWS02860
        D         *10                                     HWS02870
        S      L  TBBN                                    HWS02880
        STO       ETDK                                    HWS02890
        LD        TIME                                    HWS02900
        BNZ       INTEG                                   HWS02910
        LD        ENDK                                    HWS02920
        STO       ENDK1                                   HWS02930
        LD        EPDK                                    HWS02940
        STO       EPDK1                                   HWS02950
        LD        ETDK                                    HWS02960
        STO       ETDK1                                   HWS02970
        LD     2  VT036                                   HWS02980
        STO       ENK                                     HWS02990
        BNN       STENL
        LD        *0
        S         ENK
STENL   STO       ENKL
        LD     2  VT037                                   HWS03010
        SRT       4
        STO       EPK                                     HWS03030
        BNN       STEPL
        LD        *0
        S         EPK
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
STEPL STO      EPKL
      LD     2 VTO38                         HWS03050
      STO      ETK                           HWS03060
      STO      ETKL                          HWS03070
      LD       =1                            HWS03080
      STO      TIME                          HWS03090
      B      L INTEG
      LORG                                   HWS03110
*GENERATE EN EP ET                           HWS03120
TIME  DC       0
ENDK  DC       *-*                           HWS03140
ENDK1 DC       *-*                           HWS03150
EPDK  DC       *-*                           HWS03160
EPDK1 DC       *-*                           HWS03170
ETDK  DC       *-*                           HWS03180
ETDK1 DC       *-*                           HWS03190
DT    DC       15                            HWS03200
ENK   DC       *-*                           HWS03210
ENKL  DC       *-*                           HWS03220
EPK   DC       *-*                           HWS03230
EPKL  DC       *-*                           HWS03240
ETK   DC       *-*                           HWS03250
ETKL  DC       *-*                           HWS03260
*                                            HWS03280
INTEG EQU      *                             HWS03290
*                        CALCULATE EN        HWS03300
      LD       ENDK
      A        ENDK1
      M        DT
      SLT      3            EN SCALED UP BY 8
      D        =375
      A        ENK                           HWS03400
      STO      ENK                           HWS03410
*                        CALCULATE EP        HWS03420
      LD       EPDK
      A        EPDK1
      M        DT
      D        =375
      M      L KPFN1
      D        =1000
      A        EPK                           HWS03490
      STO      EPK                           HWS03500
*                        CALCULATE ET        HWS03510
      LD       ETDK                          HWS03520
      M        =3                            HWS03530
      SLT      16                            HWS03540
      S        ETDK1                         HWS03550
      M        DT                            HWS03560
      D        =2000                         HWS03570
      A        ETK                           HWS03580
      STO      ETK                           HWS03590
*                        LIMLTS ON EN EP ET  HWS03600
      LD       ENK                           HWS03610
      BN       MW1                           HWS03620
      S        ENKL                          HWS03630
      BNP      MW2                           HWS03640
      LD       ENKL                          HWS03650
      STO      ENK                           HWS03660
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
        B     L  MW2                                          HWS03670
MW1     EQU      *                                            HWS03680
        LD       ENK                                          HWS03690
        A        ENKL                                         HWS03700
        BP       MW2                                          HWS03710
        LD       =0                                           HWS03720
        S        ENKL                                         HWS03730
        STO      ENK                                          HWS03740
MW2     EQU      *                                            HWS03750
        LD       EPK                                          HWS03760
        BN       MW3                                          HWS03770
        S        EPKL                                         HWS03780
        BNP      MW4                                          HWS03790
        LD       EPKL                                         HWS03800
        STO      EPK                                          HWS03810
        B     L  MW4                                          HWS03820
MW3     EQU      *                                            HWS03830
        LD       EPK                                          HWS03840
        A        EPKL                                         HWS03850
        BP       MW4                                          HWS03860
        LD       =0                                           HWS03870
        S        EPKL                                         HWS03880
        STO      EPK                                          HWS03890
MW4     EQU      *                                            HWS03900
        LD       ETK                                          HWS03910
        BN       MW5                                          HWS03920
        S        ETKL                                         HWS03930
        BNP      MW6                                          HWS03940
        LD       ETKL                                         HWS03950
        STO      ETK                                          HWS03960
        B     L  MW6                                          HWS03970
MW5     EQU      *                                            HWS03980
        LD       ETK                                          HWS03990
        A        ETKL                                         HWS04000
        BP       MW6                                          HWS04010
        LD       =0                                           HWS04020
        S        ETKL                                         HWS04030
        STO      ETK                                          HWS04040
        B     L  MW6                                          HWS04050
        LORG                                                  HWS04060
*                     AGE DERIVATIVES                         HWS04070
MW6     EQU      *                                            HWS04080
        LD    L  ENDK                                         HWS04090
        STO   L  ENDK1                                        HWS04100
        LD    L  EPDK                                         HWS04110
        STO   L  EPDK1                                        HWS04120
        LD    L  ETDK                                         HWS04130
        STO   L  ETDK1                                        HWS04140
*                                                             HWS04150
*                    INTERPOLATE FOR PT3 AND PT5              HWS04160
*                    AS A FUNCTION OF PLA                     HWS04170
PLA     EQU      *
        LD       NPL1                                         HWS04180
        S     *  VT128                                        HWS04190
        BN       MDW1                                         HWS04200
        LD    L  P3E1                                         HWS04210
        STO   L  P3PL                                         HWS04220
        LD    L  P5F1                                         HWS04230
```

Table E-8. Equilibrium - Pressure Subprogram (Continued)

```
      STO  L  P5PL                                          HWS04240
      LD   L  WEF1                                          HWS04250
      STO  L  WEFN                                          HWS04260
      B    L  MDW6                                          HWS04270
MDW1  LD      NPL4                                          HWS04280
      S     2 VT128                                         HWS04290
      BP      MDW2                                          HWS04300
      LD   L  P3E4                                          HWS04310
      STO  L  P3PL                                          HWS04320
      LD   L  P5E4                                          HWS04330
      STO  L  P5PL                                          HWS04340
      LD   L  WEF4                                          HWS04350
      STO  L  WEFN                                          HWS04360
      B    L  MDW6                                          HWS04370
MDW2  LD   L  NPL2                                          HWS04380
      S     2 VT128                                         HWS04390
      BN      MDW3                                          HWS04400
      SRT     9
      D       *3300                                         HWS04420
      STO     CX1                                           HWS04430
      LD      *128
      S       CX1                                           HWS04450
      STO     CX2                                           HWS04460
      LD   L  P3E1                                          HWS04470
      STO     P3L                                           HWS04480
      LD   L  P3E2                                          HWS04490
      STO     P3M                                           HWS04500
      LD   L  P5E1                                          HWS04510
      STO     P5L                                           HWS04520
      LD   L  P5E2                                          HWS04530
      STO     P5M                                           HWS04540
      LD   L  WEF1                                          HWS04550
      STO  L  WEFL                                          HWS04560
      LD   L  WEF2                                          HWS04570
      STO  L  WEFM                                          HWS04580
      B    L  MDW5                                          HWS04590
      LORG                                                  HWS04600
MDW3  LD      NPL3                                          HWS04610
      S     2 VT128                                         HWS04620
      BN      MDW4                                          HWS04630
      SRT     9
      D       *2475                                         HWS04650
      STO     CX1                                           HWS04660
      LD      *128
      S       CX1                                           HWS04680
      STO     CX2                                           HWS04690
      LD   L  P3E2                                          HWS04700
      STO     P3L                                           HWS04710
      LD   L  P3E3                                          HWS04720
      STO     P3M                                           HWS04730
      LD   L  P5E2                                          HWS04740
      STO     P5L                                           HWS04750
      LD   L  P5E3                                          HWS04760
      STO     P5M                                           HWS04770
      LD   L  WEF2                                          HWS04780
      STO  L  WEFL                                          HWS04790
      LD   L  WEF3                                          HWS04800
      STO  L  WEFM                                          HWS04810
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
      B     L  MDW5                                   HWS04820
NPL1  DC       8250                                   HWS04830
NPL2  DC       11550                                  HWS04840
NPL3  DC       14025                                  HWS04850
NPL4  DC       16500                                  HWS04860
CX1   DC       *-*                                    HWS04870
CX2   DC       *-*                                    HWS04880
P3L   DC       *-*                                    HWS04890
P3M   DC       *-*                                    HWS04900
P5L   DC       *-*                                    HWS04910
P5M   DC       *-*                                    HWS04920
WEFL  DC       *-*                                    HWS04940
WEFM  DC       *-*                                    HWS04950
SUMX  BSS   E  0
      DC       0
      DC       0
MDW4  LD       NPL4                                   HWS04960
      S     *  VT128                                  HWS04970
      SRT      9
      D        *2475                                  HWS04990
      STO      CX1                                    HWS05000
      LD       *128
      S        CX1                                    HWS05020
      STO      CX2                                    HWS05030
      LD    L  P3E3                                   HWS05040
      STO      P3L                                    HWS05050
      LD    L  P3E4                                   HWS05060
      STO      P3M                                    HWS05070
      LD    L  P5E3                                   HWS05080
      STO      P5L                                    HWS05090
      LD    L  P5E4                                   HWS05100
      STO      P5M                                    HWS05110
      LD    L  WEF3                                   HWS05120
      STO   L  WEFL                                   HWS05130
      LD    L  WEF4                                   HWS05140
      STO   L  WEFM                                   HWS05150
MDW5  LD       P3L                                    HWS05160
      M        CX1                                    HWS05170
      STD      SUMX
      LD       P3M                                    HWS05200
      M        CX2                                    HWS05210
      AD       SUMX
      SRT      7
      SLT      16
      STO      P3PL                                   HWS05250
      LD       P5L                                    HWS05260
      M        CX1                                    HWS05270
      STD      SUMX
      LD       P5M                                    HWS05300
      M        CX2                                    HWS05310
      AD       SUMX
      SRT      7
      SLT      16
      STO      P5PL                                   HWS05350
      LD    L  WEFL                                   HWS05360
      M        CX1                                    HWS05370
      STD      SUMX
      LD       WEFM                                   HWS05400
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
        M          CX2                                                   HWS0541O
        AD         SUMX
        SRT        7
        SLT        16
        STO        WEFN                                                  HWS0545O
        B      L   MDW6                                                  HWS0546O
        LORG                                                             HWS0547O
MDW6    EQU        *                                                     HWS0551O
        LD     L   P5PL                                                  HWS0552O
        STO     2  VT162                                                 HWS0553O
        LD     L   P3PL                                                  HWS0554O
        STO     2  VT163                                                 HWS0555O
        LD     L   ENK                                                   HWS0556O
        STO     2  VT164                                                 HWS0557O
        LD     L   WEFN                                                  HWS0558O
        STO     2  VT165                                                 HWS0559O
        LD     L   KEFN1                                                 HWS0560O
        STO     2  VT166                                                 HWS0561O
        LD     L   KEFN2                                                 HWS0562O
        STO     2  VT167                                                 HWS0563O
        LD     L   KEFN3                                                 HWS0564O
        STO     2  VT168                                                 HWS0565O
        LD     L   KEFN4                                                 HWS0566O
        STO     2  VT169                                                 HWS0567O
        LD     L   PT5NB                                                 HWS0568O
        STO     2  VT170                                                 HWS0569O
        LD     L   PT3NB                                                 HWS0570O
        STO     2  VT171                                                 HWS0571O
        LD     L   EPK                                                   HWS0572O
        STO     2  VT172                                                 HWS0573O
        LD     L   WPFN                                                  HWS0574O
        STO     2  VT173                                                 HWS0575O
        LD     L   KPFN2                                                 HWS0576O
        STO     2  VT174                                                 HWS0577O
        LD     L   KPFN3                                                 HWS0578O
        STO     2  VT175                                                 HWS0579O
        LD     L   KPFN4                                                 HWS0580O
        STO     2  VT176                                                 HWS0581O
*                                                                        HWS0548O
*       CALCULATE X-XO   FOR EQUILIBRIUM PRESSURE                        HWS0549O
*                                                                        HWS0550O
MEPT    EQU        *
        LD      2  VT157                                                 HWS0582O
        S       2  VT128                                                 HWS0583O
        STO        ME1                                                   HWS0584O
        STO     2  VT196
        LD      2  VT108                                                 HWS0585O
        S      L   P5PL                                                  HWS0588O
        STO        ME2                                                   HWS0589O
        S       2  VT073  *                                              HWS0746O
        STO     2  VT197
        LD      2  VT102                                                 HWS0590O
        S      L   P3PL                                                  HWS0593O
        STO        ME3                                                   HWS0594O
        STO     2  VT198
        LD     L   ENK                                                   HWS0595O
        STO        ME4                                                   HWS0596O
*                                                                        HWS0597O
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
        LD      2 VT106                                   HWS05980
        S     L   PT5NB                                   HWS06010
        STO       MP2                                     HWS06020
        STO     2 VT199
        LD      2 VT102                                   HWS06030
        S     L   PT3NB                                   HWS06060
        STO       MP3                                     HWS06070
        STO     2 VT200
        LD    L   EPK                                     HWS06080
        STO       MP4                                     HWS06090
        B     L   FREQE                                   HWS06100
ME1     DC        ***                                     HWS06110
ME2     DC        ***                                     HWS06120
ME3     DC        ***                                     HWS06130
ME4     DC        ***                                     HWS06140
MP1     DC        ***                                     HWS06150
MP2     DC        ***                                     HWS06160
MP3     DC        ***                                     HWS06170
MP4     DC        ***                                     HWS06180
KEFN1   DC        ***                                     HWS06190
KEFN2   DC        ***                                     HWS06200
KEFN3   DC        ***                                     HWS06210
KEFN4   DC        ***                                     HWS06220
WEFN    DC        ***                                     HWS06230
P3PL    DC        ***                                     HWS06240
P5PL    DC        ***                                     HWS06250
KPFN1   DC        ***                                     HWS06260
KPFN2   DC        ***                                     HWS06270
KPFN3   DC        ***                                     HWS06280
KPFN4   DC        ***                                     HWS06290
WPFN    DC        ***                                     HWS06300
PT3NB   DC        ***                                     HWS06310
PT5NB   DC        ***                                     HWS06320
WTFN    DC        ***                                     HWS06330
AWN     DC        ***                                     HWS06340
WFMNN   DC        ***
TBBN    DC        ***                                     HWS06370
SUMEF   DC        ***                                     HWS06380
*
*  CALCULATE FUEL REQ. ST FOR SPEED AND PRESSURE
*
FREQE   EQU       *                                       HWS06450
        LD    L   KEFN1                                   HWS06460
        M         ME1                                     HWS06470
        SLT       7
        STO     2 VT201
        STO       SUMEF                                   HWS06490
        LD    L   KEFN2                                   HWS06500
        M         ME2                                     HWS06510
        D         *100
        SRT       7
        STO     2 VT202
        A         SUMEF                                   HWS06530
        STO       SUMEF                                   HWS06540
        LD    L   KEFN3                                   HWS06550
        M         ME3                                     HWS06560
        D         *100
        SRT       9
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
       STO    2 VT203
       A        SUMEF                                        HWS06580
       STO      SUMEF                                        HWS06590
       LD     L KEFN4                                        HWS06600
       M        ME4                                          HWS06610
       SLT      4
       STO    2 VT204
       A        SUMEF                                        HWS06630
       STO      SUMFF                                        HWS06650
       LD     L WEFN                                         HWS06670
       SRT      2
       A        SUMEF                                        HWS06700
       STO      SUMEF                                        HWS06720
       B      L FREQP                                        HWS06770
       LORG                                                  HWS06780
SUMPF  DC       ***                                          HWS06790
FREQP  EQU      *                                            HWS06800
       LD     L KPFN2                                        HWS06850
       M        MP2                                          HWS06860
       D        *100
       SRT      2
       STO      SUMPF                                        HWS06890
       STO    2 VT205
       LD     L KPFN3                                        HWS06900
       M        MP3                                          HWS06910
       D        *100
       SRT      2
       STO    2 VT206
       A        SUMPF                                        HWS06930
       STO      SUMPF                                        HWS06940
       LD     L KPFN4                                        HWS06950
       M        MP4                                          HWS06960
       D        *100
       SRT      2
       STO    2 VT207
       A        SUMPF                                        HWS06980
       STO      SUMPF                                        HWS07010
       LD     L WPFN                                         HWS07020
       SRT      2
       A        SUMPF                                        HWS07050
       STO      SUMPF                                        HWS07070
       B      L FREQT                                        HWS07120
       LORG                                                  HWS07130
SUMTF  DC       ***                                          HWS07140
FREQT  EQU      *                                            HWS07150
       LD       *32700                                       HWS07160
       STO      SUMTF                                        HWS07170
       B      L MDSWT                                        HWS07180
       LORG                                                  HWS07190
ONE    DC       3276                                         HWS07200
TWO    DC       6552                                         HWS07210
THREE  DC       9828                                         HWS07220
WFMOD  DC       ***                                          HWS07230
*
*  MODE SWITCHING LOGIC
*
MDSWT  EQU      *                                            HWS07240
       LD     L SUMEF                                        HWS07250
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
       STO   2 VT071                                        HWS07260
       LD    L SUMPF                                        HWS07270
       STO   2 VT072                                        HWS07280
       LD    L SUMTF                                        HWS07290
       STO   2 VT073                                        HWS07300
       CMP   2 VT072                                        HWS07310
       LD    2 VT072                                        HWS07320
       NOP                                                  HWS07330
       STO     WFMOD                                        HWS07340
       CMP   2 VT071                                        HWS07350
       LD    2 VT071                                        HWS07360
       NOP                                                  HWS07370
       STO   2 VT180                                        HWS07380
       BN      MINFL
       M     L *13                                          HWS06990
       SLT     16                                           HWS07000
       STO   2 VT180
       LD    2 VT180
       S     L WFMNN
       BNN     MINSS
MINFL  LD    L WFMNN
       STO   2 VT180
MINSS  EQU     *
       LD    2 VT180                                        HWS07390
       SRT     16
       D       *13
       S     2 VT071                                        HWS07400
       BNZ     MIKE1                                        HWS07410
       LD      ONE                                          HWS07420
       STO   2 VT074                                        HWS07430
       B     L RQAIB                                        HWS07440
MIKE1  LD    2 VT180                                        HWS07450
       SRT     16
       D       *13
       S     2 VT072                                        HWS07460
       BNZ     MIKE2                                        HWS07470
       LD      TWO                                          HWS07480
       STO   2 VT074                                        HWS07490
       B     L RQAIB                                        HWS07500
MIKE2  LD      THREE                                        HWS07510
       STO   2 VT074                                        HWS07520
       B     L RQAIB                                        HWS07530
KLAGD  DC      49
K1NUM  DC      31
K2NUM  DC.     9
YNM1   DC      *-*
UNM1   DC      *-*
TEMF   BSS   E 0
       DC      0
       DC      0
SWLAG  DC      *-*
*
*  FINAL FUEL REQUEST IS LAGGED HERE
*
RQAIB  EQU     *                                            HWS07540
       LD    L SWLAG
       BNZ     FILT
       LD    L *123
```

```
        STO   L  SWLAG
        LD     2 VT180
        STO   L  YNM1
        STO   L  UNM1
        B     L  DONOZ
FILT    LD    L  UNM1
        M     L  K2NUM
        STD   L  TEMF
        LD     2 VT180
        STO   L  UNM1
        M     L  K2NUM
        AD    L  TEMF
        STD   L  TEMF
        LD    L  YNM1
        M     L  K1NUM
        AD    L  TEMF
        D     L  KLAGD
        STO   L  YNM1
        STO    2 VT180
*
*  EXHAUST  NOZZLE REQUEST CALCULATION
*
DONOZ EQU        *
        LD     2 VT074
        S     L  ONE
        BNZ      GT10
        LD     2 VT128
        STO   L  NAB
        B     L  CALAB
GT10    LD     2 VT157
        STO   L  NAB
CALAB LD      L  NAB
        S     L  *14025
        BNN      GT11
        LD     2 VT034
        STO    2 VT081
        B     L  CONT
GT11    S     L  *2475
        BN       GT12
        LD     2 VT035
        STO    2 VT081
        B     L  CONT
GT12    LD     2 VT034
        S      2 VT035
        STO   L  ANOZN
        LD    L  *16500
        S     L  NAB
        M     L  ANOZN
        D     L  *2475
        A      2 VT035
        STO    2 VT081
        B     L  CONT
        LORG
NAB     DC       *-*
ANOZN DC         *-*
CONT    EQU      *                                          HWS07700
XR1     LDX   L1 *-*                                        HWS07710
        BSC   I  HAFCT                                      HWS07720
```

Table B-8. Equilibrium - Pressure Subprogram (Continued)

```
VT071 EQU    *71                                   HWS07730
VT072 EQU    *72                                   HWS07740
VT073 EQU    *73                                   HWS07750
VT074 EQU    *74                                   HWS07760
VT081 EQU    *81                                   HWS07770
VT082 EQU    *82                                   HWS07780
VT083 EQU    *83                                   HWS07790
VT157 EQU    +30                                   HWS07800
VT180 EQU    +53                                   HWS07810
VT128 EQU    +1                                    HWS07820
VT102 EQU    *102                                  HWS07830
VT108 EQU    *108                                  HWS07840
VT097 EQU    *97                                   HWS07850
VT036 EQU    *36                                   HWS07860
VT037 EQU    *37                                   HWS07870
VT038 EQU    *38                                   HWS07880
VT039 EQU    *39                                   HWS07890
VT162 EQU    +35                                   HWS07900
VT163 EQU    +36                                   HWS07910
VT164 EQU    +37                                   HWS07920
VT165 EQU    +38                                   HWS07930
VT166 EQU    +39                                   HWS07940
VT167 EQU    +40                                   HWS07950
VT168 EQU    +41                                   HWS07960
VT169 EQU    +42                                   HWS07970
VT170 EQU    +43                                   HWS07980
VT171 EQU    +44                                   HWS07990
VT172 EQU    +45                                   HWS08000
VT173 EQU    +46                                   HWS08010
VT174 EQU    +47                                   HWS08020
VT175 EQU    +48                                   HWS08030
VT176 EQU    +49                                   HWS08040
VT206 EQU    +79
VT207 EQU    +80
VT196 EQU    +69
VT197 EQU    +70
VT198 EQU    +71
VT199 EQU    +72
VT200 EQU    +73
VT201 EQU    +74
VT202 EQU    +75
VT203 EQU    +76
VT204 EQU    +77
VT205 EQU    +78
VT012 EQU    *12
VT013 EQU    *13
VT014 EQU    *14
VT015 EQU    *15
VT016 EQU    *16
VT017 EQU    *17
VT018 EQU    *18
VT019 EQU    *19
VT020 EQU    *20
VT021 EQU    *21
VT022 EQU    *22
VT023 EQU    *23
VT040 EQU    *40
VT041 EQU    *41
```

Table B-8. Equilibrium - Pressure Subprogram (Concluded)

```
VT042 EQU     *42
VT043 EQU     *43
VT044 EQU     *44
VT045 EQU     *45
VT046 EQU     *46
VT047 EQU     *47
VT048 EQU     *48
VT049 EQU     *49
VT050 EQU     *50
VT061 EQU     *61
VT062 EQU     *62
VT063 EQU     *63
VT064 EQU     *64
VT065 EQU     *65
VT066 EQU     *66
VT067 EQU     *67
VT068 EQU     *68
VT069 EQU     *69
VT034 EQU     *34
VT035 EQU     *35
      END
```

Table B-9. Standard Trim Adjustments in Bounds Program (Equilibrium Pressure)

```
// JOB          VDISK    12 JUN 74 08.612 HRS
// DMP    12 JUN 74 08.612 HRS
*DELETE                  GTECT
DMP FUNCTION COMPLETED
// ASM GTECT    12 JUN 74 08.613 HRS                                              HWE00010
*OVERFLOW SECTORS ,,,9                                                            HWE00020
*LIST                                                                             HWE00030
*XREF                                                                             HWE00040
*ONE WORD INTEGERS                                                                HWE00050
*COMMON IDUMY(127),IVTOO,JDUMY(127),IWTD,MEAST(64),IASCW(2)                       HWE00060
0000      078C50E3     1          ENT        GTECT                                    HWE00070
0000 0    0000         2   GTECT  DC         *-*                                      HWE00080
0001 01   6D000512     3          STX   L1   XR1+1                                    HWE00090
0003 01   6E000514     4          STX   L2   XR2+1                                    HWE00100
0005 01   6F000516     5          STX   L3   XR3+1                                    HWE00110
                       6   *                                                          HWE00120
0007 03   6700FEC0     7          LDX   L3   MEAST-63                                 HWE00130
0009 03   6600FF80     8          LDX   L2   IVTOO                                    HWE00140
000B 00   65000000     9          LDX   L1   0                                        HWE00150
000D 0    C03F        10          LD         =0                                       HWE00160
                      11   *                                                          HWE00170
000E 01   4C000OF7    12          B     L    START                                    HWE00180
0010                  13   RSTAL  EQU        *        RESET ALL DIGITAL ADJUST        HWE00190
0010 0    C03E        14          LD         ST001                                    HWE00200
0011 0    D2FF        15          STO   2    VT001                                    HWE00210
0012 0    C03D        16          LD         ST002                                    HWE00220
0013 0    D2FE        17          STO   2    VT002                                    HWE00230
0014 0    C03C        18          LD         ST003                                    HWE00240
0015 0    D2FD        19          STO   2    VT003                                    HWE00250
0016 0    C03B        20          LD         ST004                                    HWE00260
0017 0    D2FC        21          STO   2    VT004                                    HWE00270
0018 0    C03A        22          LD         ST005                                    HWE00280
0019 0    D2FB        23          STO   2    VT005                                    HWE00290
001A 0    C039        24          LD         ST006                                    HWE00300
001B 0    D2FA        25          STO   2    VT006                                    HWE00310
001C 0    C038        26          LD         ST007                                    HWE00320
001D 0    D2F9        27          STO   2    VT007                                    HWE00330
001E 0    C037        28          LD         ST008                                    HWE00340
001F 0    D2F8        29          STO   2    VT008                                    HWE00350
0020 0    C036        30          LD         ST009                                    HWE00360
0021 0    D2F7        31          STO   2    VT009                                    HWE00370
0022 0    C035        32          LD         ST010                                    HWE00380
0023 0    D2F6        33          STO   2    VT010                                    HWE00390
0024 0    C034        34          LD         ST011                                    HWE00400
0025 0    D2F5        35          STO   2    VT011                                    HWE00410
0026 0    C033        36          LD         ST012                                    HWE00420
0027 0    D2F4        37          STO   2    VT012                                    HWE00430
0028 0    C032        38          LD         ST013                                    HWE00440
0029 0    D2F3        39          STO   2    VT013                                    HWE00450
002A 0    C031        40          LD         ST014                                    HWE00460
002B 0    D2F2        41          STO   2    VT014                                    HWE00470
002C 0    C030        42          LD         ST015                                    HWE00480
002D 0    D2F1        43          STO   2    VT015                                    HWE00490
002E 0    C02F        44          LD         ST016                                    HWE00500
002F 0    D2F0        45          STO   2    VT016                                    HWE00510
0030 0    C02E        46          LD         ST017                                    HWE00520
0031 0    D2EF        47          STO   2    VT017                                    HWE00530
0032 0    C02D        48          LD         ST018                                    HWE00540
0033 0    D2EE        49          STO   2    VT018                                    HWE00550
0034 0    C02C        50          LD         ST019                                    HWE00560
```

Table B-9. Standard Trim Adjustments in Bounds Program (Equilibrium Pressure) (Continued)

0035 0	D2ED	51		STO	2 VT019		HWE00570
0036 0	C02B	52		LD	ST020		HWE00580
0037 0	D2EC	53		STO	2 VT020		HWE00590
0038 0	C02A	54		LD	ST021		HWE00600
0039 0	D2EB	55		STO	2 VT021		HWE00610
003A 0	C029	56		LD	ST022		HWE00620
003B 0	D2EA	57		STO	2 VT022		HWE00630
003C 0	C028	58		LD	ST023		HWE00640
003D 0	D2E9	59		STO	2 VT023		HWE00650
003E 0	C027	60		LD	ST024		HWE00660
003F 0	D2E8	61		STO	2 VT024		HWE00670
0040 0	C026	62		LD	ST025		HWE00680
0041 0	D2E7	63		STO	2 VT025		HWE00690
0042 0	C025	64		LD	ST026		HWE00700
0043 0	D2E6	65		STO	2 VT026		HWE00710
0044 0	C024	66		LD	ST027		HWE00720
0045 0	D2E5	67		STO	2 VT027		HWE00730
0046 0	C023	68		LD	ST028		HWE00740
0047 0	D2E4	69		STO	2 VT028		HWE00750
0048 0	C022	70		LD	ST029		HWE00760
0049 0	D2E3	71		STO	2 VT029		HWE00770
004A 0	C021	72		LD	ST030		HWE00780
004B 0	D2E2	73		STO	2 VT030		HWE00790
004C 0	7048	74		B	STTVT		HWE00800
		75		LORG			HWE00810
004D 0	0000	76	*	DC	0		
		77	*			SPEED CONTROL FIG10-3&4	HWE00820
004E 0	0000	78	ST000	DC	0		HWE00830
004F 0	0000	79	ST001	DC	0	IDLE SPEED TRIM	HWE00840
0050 0	0000	80	ST002	DC	0	MAX SPEED TRIM	HWE00850
0051 0	4E20	81	ST003	DC	20000		HWE00860
0052 0	0000	82	ST004	DC	0	BRANCH COMMAND 64+	HWE00870
0053 0	1000	83	ST005	DC	4096	N INTEGRATION INC	HWE00880
0054 0	1388	84	ST006	DC	5000	N INT PRESS GAIN	HWE00890
0055 0	F000	85	ST007	DC	-4096	N INT DECREASE	HWE00900
0056 0	EC78	86	ST008	DC	-5000	N INT DEC PRESS GAIN	HWE00910
		87	*				HWE00920
		88	*		FIG10-5	PROP.TEMPERATURE CONTROL	HWE00930
0057 0	0000	89	ST009	DC	0	SPEED CONTROL SELECTION	HWE00940
0058 0	32C8	90	ST010	DC	11000)		HWE00950
0059 0	0000	91	ST011	DC	0	ZERO FLOW ADJUST	HWE00960
		92	*		HONEYWELL ST VALUES		
		93	*				
005A 0	F290	94	ST012	DC	-3440	N GAIN (50 ,E)	
005B 0	0177	95	ST013	DC	519	WF (50 ,E)	
005C 0	0000	96	ST014	DC	2200	PT3 (50 ,E)	
005D 0	0180	97	ST015	DC	432	EN GAIN (50 ,E)	
005E 0	F820	98	ST016	DC	-2016	N GAIN (70 ,E)	
005F 0	0315	99	ST017	DC	693	WF (70 ,E)	
0060 0	0000	100	ST018	DC	3550	PT3 (70 ,E)	
0061 0	0190	101	ST019	DC	400	EN GAIN (70 ,E)	
0062 0	F860	102	ST020	DC	-1952	N GAIN (85 ,E)	
0063 0	04A6	103	ST021	DC	934	WF (85 ,E)	
0064 0	0000	104	ST022	DC	3500	PT3 (85 ,E)	
0065 0	0380	105	ST023	DC	896	EN GAIN (85 ,E)	
		106	*				
		107	*		END HONEYWELL ST VALUES		

Table B-9. Standard Trim Adjustments in Bounds Program (Equilibrium Pressure) (Concluded)

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			108	*				
0066	0	1770	109	ST024	DC	6000	ZERO N RATIOS INTERCEPT	HWE01140
0067	0	A240	110	ST025	DC	-24000	BACK SLOPE SPEED BREAK PT	HWE01150
0068	0	4000	111	ST026	DC	16384		
			112	*				HWE01170
			113	*			FIGURE10-8 RATIOS INTEGRATION	HWE01180
0069	0	7FF8	114	ST027	DC	32760		
006A	0	0000	115	ST028	DC	0		
006B	0	0000	116	ST029	DC	0	MINIMUM RATIOS SLOPE	HWE01210
006C	0	5014	117	ST030	DC	20500	MINIMUM RATIOS LEVEL	HWE01220
006D	0	0000	118	ST031	DC	0		HWE01230
006E	0	7FF8	119	ST032	DC	32760	VALVE MAXIMUM POSITION	HWE01240
006F	0	0000	120	ST033	DC	0	VALVE MINIMUM POSITION	HWE01250
0070	0	25A8	121	ST034	DC	9640		
0071	0	0A5A	122	ST035	DC	2650		
			123	*				
			124	*		HONEYWELL ST VALUES		
			125	*				
0072	0	0640	126	ST036	DC	1600		
0073	0	0640	127	ST037	DC	1600		
0074	0	000A	128	ST038	DC	10		
0075	0	0010	129	ST039	DC	16		
0076	0	F0A0	130	ST040	DC	-3936	N GAIN (100,E)	
0077	0	0960	131	ST041	DC	1648	WF (100,E)	
0078	0	0000	132	ST042	DC	8000	PT3 (100,E)	
0079	0	0930	133	ST043	DC	2352	EN GAIN (100,E)	
007A	0	0C11	134	ST044	DC	3089	FUG GAIN (50 ,P)	
007B	0	23B0	135	ST045	DC	9136	PT5 GAIN (50 ,P)	
007C	0	D610	136	ST046	DC	-10736	PT3 GAIN (50 ,P)	
007D	0	030B	137	ST047	DC	651	EP GAIN (50 ,P)	
007E	0	2400	138	ST048	DC	9216	FUG GAIN (70 ,P)	
007F	0	F5E0	139	ST049	DC	-2592	PT5 GAIN (70 ,P)	
0080	0	F200	140	ST050	DC	-3584	PT3 GAIN (70 ,P)	
			141	*				
			142	*		END HONEYWELL ST VALUES		
			143	*				
			144	*				HWE01460
			145	*			FIGURE10-12 IGV & BLEED CONTR	HWE01470
0081	0	0000	146	ST051	DC	0	LOW N TRIM OF IGV	HWE01480
0082	0	3E80	147	ST052	DC	16000	HIGH N TRIM OF IGV	HWE01490
0083	0	0000	148	ST053	DC	0	LOW N TRIM OF BLEEDS	HWE01500
0084	0	3E80	149	ST054	DC	16000	HIGH N TRIM OF BLEEDS	HWE01510
			150	*				HWE01520
			151	*			FIGURE10-14 NOZZLE CONTROL	HWE01530
0085	0	105E	152	ST055	DC	4190	NOZZLE FLAT	BEN01530
0086	0	40D8	153	ST056	DC	16600	T5 REQUEST	HWE01550
0087	0	4000	154	ST057	DC	16384	T5 CONTROL GAIN	HWE01560
0088	0	0000	155	ST058	DC	0		HWE01570
0089	0	0000	156	ST059	DC	0		HWE01580
008A	0	0000	157	ST060	DC	0		HWE01590
008B	0	06CC	158	ST061	DC	1000	EP GAIN (70 ,P)	
008C	0	03B0	159	ST062	DC	944	FUG GAIN (85 ,P)	
008D	0	0B90	160	ST063	DC	2960	PT5 GAIN (85 ,P)	
008E	0	EFE0	161	ST064	DC	-4128	PT3 GAIN (85 ,P)	
008F	0	0A0D	162	ST065	DC	2000	EP GAIN (85 ,P)	
0090	0	16C0	163	ST066	DC	5824	FUG GAIN (100,P)	
0091	0	09C0	164	ST067	DC	2496	PT5 GAIN (100,P)	
0092	0	F4F0	165	ST068	DC	-2832	PT3 GAIN (100,P)	
0093	0	0D96	166	ST069	DC	2400	EP GAIN (100,P)	
0094	0	0000	167	ST070	DC	0		

Table B-10. Glossary for Equilibrium-Temperature Control

VT Number	Transferred to (Program Label)	Description	Standard Value (Defined in the Bendix Program)
009	---	Logic switch: If VT009 > 123 the Honeywell controller is in; otherwise not	0
012	KEF11	Speed control gain associated with $(N-N_{pla})$ at 8250 rpm	(-215 x 16)
013	WEF1	Open-loop fuel-speed control at 8250 rpm	519 lb/hr
014	P3P1	Open-loop PT3-speed control at 8250 rpm	2200 psi x 100
015	KEF14	Speed control gain associated with EN at 825 rpm	(27) x 16
016	KEF21	Speed control gain associated with $(N-N_{pla})$ at 11,550 rpm	(-126) x 16
017	WEF2	Open-loop fuel-speed control at 11,550 rpm	693 lb/hr
018	P3P2	Open-loop PT3 - speed control at 11,550 rpm	3550 psi x 100
019	KEF24	Speed control gain associated with EN at 11,550 rpm	(25) x 16
020	KEF31	Speed control gain associated with $(N-N_{pla})$ at 14,025 rpm	(-122) x 16
021	WEF3	Open-loop fuel-speed control at 14,025 rpm	934 lb/hr
022	P3P3	Open-loop PT3-speed control at 14,025 rpm	5500 psi x 100
023	KEF34	Speed control gain associated with EN at 14,025 rpm	(56) x 16
026	---	If this number is made large, Bendix bound on fuel will not be in effect	2^{14}
028	---	Logical switch: if VTO28 = 64 Honeywell nozzle is used; otherwise not	0

Table B-10. Glossary for Equilibrium-Temperature Control (Continued)

VT Number	Transferred to (Program Label)	Description	Standard Value (Defined in the Bendix Program)
034	---	Exhaust request: open	9640
035	---	Exhaust request: closed	2650
036	ENK, ENKL	Initial value of integral speed and limits valve	1600
038	ETK, ETKL	Initial value of integral temperature and limiting valve	25,600
039	---	Logical switch: VT089 = 16 initialize everything. VT039 = 64 initializes EN and ET only	16
040	KEF41	Speed control gain associated with $(N-N_{pla})$ at 16,500 rpm	(-246) x 16
041	WEF4	Open-loop fuel-speed control at 16,500 rpm	1648 lb/hr
042	P3P4	Open-loop PT3-speed control at 16,500 rpm	8000 psi x 100
043	KEF44	Speed control gain associated with EN at 16,500 rpm	(147) x 16
044	KTF11	Temperature control gain - (PT5-PT5δ) - at 8250 rpm	(557) x 16
045	KTF12	Temperature control gain - (PT3-PT3δ) - at 8250 rpm	(-736) x 16
046	KTF13	Temperature control gain - (T4WF - T4δ) at 8250 rpm	(-105) x 16
047	KTF14	Temperature control gain - ET at 8250 rpm	(52) x 16
048	WTF1	Open-loop fuel-temperature control - at 8250 rpm	651 lb/hr
049	KTF21	Temperature control gain - (PT5-PT5δ) at 11,550 rpm	(936) x 16
050	KTF22	Temperature control gain - (PT3-PT3δ) at 11,550 rpm	24585

Table B-10. Glossary for Equilibrium-Temperature Control (Continued)

VT Number	Transferred to (Program Label)	Description	Standard Value (Defined in the Bendix Program)
061	KTF23	Temperature control gain - (T4WF-T4δ) at 11,550 rpm	(-131) x 16
062	KTF24	Temperature control gain - ET at 11,550 rpm	(65) x 16
063	WTF2	Open-loop fuel - temperature control at 11,550 rpm	1000 lb/hr
064	KTF31	Temperature control gain - (PT5-PT5δ) at 14,025 rpm	(-343) x 16
065	KTF32	Temperature control gain - (PT3-PT3δ) at 14,025 rpm	4235
066	KTF33	Temperature control gain - (T4WF - T4δ) at 14,025 rpm	(-87) x 16
067	KTF34	Temperature control gain - ET at 14,025 rpm	(74) x 16
068	WTF3	Open-loop fuel - temperature control at 14,025 rpm	2000 lb/hr
069	KTF41	Temperature control gain - (PT5-PT5δ) at 16,500 rpm	6127
071	---	Fuel request - speed control 1 count = 4 lb/hr	0
073	---	Fuel request - temperature control, 1 count = 4 lb/hr	0
074	---	Mode number 3276 = speed control 6552 = temperature control 9828 = minimum fuel control	0
075	KTF42	Temperature control gain - (PT3-PT3δ) at 16,500 rpm	-8338
076	KTF43	Temperature control gain - (T4WF-T4δ)	(-4) x 16
077	KTF44	---	(108) x 16

Table B-10. Glossary for Equilibrium-Temperature Control (Concluded)

VT Number	Transferred to (Program Label)	Description	Standard Value (Defined in the Bendix Program)
078	WTF4	---	2400 lb/hr
081	---	Nozzle fuel request	---
082	TB1	T4ð at 8250 rpm	10,200 °F x 10
083	TB2	T4ð at 11,550 rpm	9000 °F x 10
084	TB3	T4ð at 14,025 rpm	10,500 °F x 10
085	TB4	T4ð at 16,500 rpm	11,600 °F x 10
086	P5T1	PT5ð at 8250 rpm	1480 psi x 100
087	P5T2	PT5ð at 11,550 rpm	1640 psi x 100
088	P5T3	PT5ð at14,025 rpm	2050 psi x 100
089	P5T4	PT5ð at 16,500 rpm	2550 psi x 100
180	---	Fuel request 3.25 counts = 1 lb/hr	---

Table B-11. Honeywell Control Program

```
// JOB          VDISK    17 JUL 74 15.584 HRS
// DMP    17 JUL 74  15.585 HRS
*DELETE              HWECT
DMP FUNCTION COMPLETED
// ASM    17 JUL 74 15.586 HRS
*OVERFLOW SECTORS ,,,9
*LIST
*XREF
*ONEWORDINTEGERS
*COMMON  IDUMY(127),IVT00,JDUMY(127),IBT0,MEAST(64),IASCW(2)
0000      089850E3           ENT       HWECT                        HWS00070
0000 0    0000       HWECT   DC        *-*                          HWS00080
0001 01   6D00050A           STX   L1  XR1+1                        HWS00090
                     *                                              HWS00100
0003 00   65000000           LDX   L1  0                            HWS00110
0005 01   4C000007           B     L   TESTN                        HWS00120
                     *                                              HWS00160
                     *INTERVAL DETERMINATION                        HWS00170
                     *                                              HWS00180
0007                 TESTN   EQU       *                            HWS00190
0007 0    C2D9               LD     2  VT039
0008 01   940000BC           S      L  =16
000A 01   4C2000AD           BNZ       MICK
000C 0    D2D9               STO    2  VT039
000D 0    C2F4               LD     2  VT012
000E 0    1884               SRT       4
000F 01   D40000FC           STO    L  KEF11
0011 0    C2F3               LD     2  VT013
0012 01   D4000100           STO    L  WEF1
0014 0    C2F2               LD     2  VT014
0015 01   D4000108           STO    L  P3T1
0017 0    C2F1               LD     2  VT015
0018 0    1884               SRT       4
0019 01   D40000FF           STO    L  KEF14
001B 0    C2F0               LD     2  VT016
001C 0    1884               SRT       4
001D 01   D4000135           STO    L  KEF21
001F 0    C2EF               LD     2  VT017
0020 01   D4000139           STO    L  WEF2
0022 0    C2EE               LD     2  VT018
0023 01   D4000141           STO    L  P3T2
0025 0    C2ED               LD     2  VT019
0026 0    1884               SRT       4
0027 01   D4000138           STO    L  KEF24
0029 0    C2EC               LD     2  VT020
002A 0    1884               SRT       4
002B 01   D400016B           STO    L  KEF31
002D 0    C2EB               LD     2  VT021
002E 01   D400016F           STO    L  WEF3
0030 0    C2EA               LD     2  VT022
0031 01   D4000177           STO    L  P3T3
0033 0    C2E9               LD     2  VT023
0034 0    1884               SRT       4
0035 01   D400016E           STO    L  KEF34
0037 0    C2D8               LD     2  VT040
0038 0    1884               SRT       4
0039 01   D40001A1           STO    L  KEF41
003B 0    C2D7               LD     2  VT041
003C 01   D40001A5           STO    L  WEF4
003E 0    C2D6               LD     2  VT042
```

Table B-11. Honeywell Control Program (Continued)

17 JUL 74 PAGE 002

```
003F 01 D40001AD    51      STO  L  P3T4
0041 0  C2D5        52      LD   2  VT043
0042 0  1884        53      SRT     4
0043 01 D40001A4    54      STO  L  KTF44
0045 0  C2D4        55      LD   2  VT044
0046 0  1884        56      SRT     4
0047 01 D4000103    57      STO  L  KTF11
0049 0  C2D3        58      LD   2  VT045
004A 0  1884        59      SRT     4
004B 01 D4000104    60      STO  L  KTF12
004D 0  C2D2        61      LD   2  VT046
004E 0  1884        62      SRT     4
004F 01 D4000105    63      STO  L  KTF13
0051 0  C2D1        64      LD   2  VT047
0052 0  1884        65      SRT     4
0053 01 D4000106    66      STO  L  KTF14
0055 0  C2D0        67      LD   2  VT048
0056 01 D4000107    68      STO  L  WTF1
0058 0  C2C         69      LD   2  VT049
0059 0  1884        70      SRT     4
005A 01 D400013C    71      STO  L  KTF21
005C 0  C2CE        72      LD   2  VT050
005D 01 D400013D    73      STO  L  KTF22
005F 0  C2C3        74      LD   2  VT061
0060 0  1884        75      SRT     4
0061 01 D400013E    76      STO  L  KTF23
0063 0  C2C2        77      LD   2  VT062
0064 0  1884        78      SRT     4
0065 01 D400013F    79      STO  L  KTF24
0067 0  C2C1        80      LD   2  VT063
0068 01 D4000140    81      STO  L  WTF2
006A 0  C2C0        82      LD   2  VT064
006B 0  1884        83      SRT     4
006C 01 D4000172    84      STO  L  KTF31
006E 0  C2BF        85      LD   2  VT065
006F 01 D4000173    86      STO  L  KTF32
0071 0  C2BE        87      LD   2  VT066
0072 0  1884        88      SRT     4
0073 01 D4000174    89      STO  L  KTF33
0075 0  C2BD        90      LD   2  VT067
0076 0  1884        91      SRT     4
0077 01 D4000175    92      STO  L  KTF34
0079 0  C2BC        93      LD   2  VT068
007A 01 D4000176    94      STO  L  WTF3
007C 0  C2BB        95      LD   2  VT069
007D 01 D40001A8    96      STO  L  KTF41
007F 0  C2B5        97      LD   2  VT075
0080 01 D40001A9    98      STO  L  KTF42
0082 0  C2B4        99      LD   2  VT076
0083 0  1884       100      SRT     4
0084 01 D40001AA   101      STO  L  KTF43
0086 0  C2B3       102      LD   2  VT077
0087 0  1884       103      SRT     4
0088 01 D40001AB   104      STO  L  KTF44
008A 0  C2B2       105      LD   2  VT078
008B 01 D40001AC   106      STO  L  WTF4
008D 01 C400005D   107      LD   L  =0
```

Table B-11. Honeywell Control Program (Continued)


```
008F 01 D40004AC   108          STO  L  SWLAG
0091 01 D4000287   109          STO  L  TIME
0093 01 D40001FD   110          STO  L  ISW
0095 0  C2AE       111          LD   2  VT082
0096 01 D400010A   112          STO  L  TB1
0098 0  C2AD       113          LD   2  VT083
0099 01 D4000143   114          STO  L  TB2
009B 0  C2AC       115          LD   2  VT084
009C 01 D4000179   116          STO  L  TB3
009E 0  C2AB       117          LD   2  VT085
009F 01 D40001AF   118          STO  L  TB4
00A1 0  C2AA       119          LD   2  VT086
00A2 01 D4000109   120          STO  L  P5T1
00A4 0  C2A9       121          LD   2  VT087
00A5 01 D4000142   122          STO  L  P5T2
00A7 0  C2A8       123          LD   2  VT088
00A8 01 D4000178   124          STO  L  P5T3
00AA 0  C2A7       125          LD   2  VT089
00AB 01 D40001AE   126          STO  L  P5T4
00AD               127   MICK   EQU     *
00AD 0  C21E       128          LD   2  VT157                   HWS00200
00AE 0  900F       129          S       =8250                   HWS00210
00AF 01 4C3000C1   130          BP      TMAX                    HWS00220
00B1 0  C00D       131          LD      =1                      HWS00230
00B2 0  D008       132          STO     NIN                     HWS00240
00B3 0  C00C       133          LD      =128
00B4 0  D004       134          STO     C1                      HWS00260
00B5 0  C007       135          LD      =0                      HWS00270
00B6 0  D003       136          STO     C2                      HWS00280
00B7 01 4C000114   137          B    L  IN1F                    HWS00290
00B9 0  0000       138   C1     DC      *-*                     HWS00130
00BA 0  0000       139   C2     DC      *-*                     HWS00140
00BB 0  0000       140   NIN    DC      *-*                     HWS00150
                   141          LORG
00BC 0  0010       142   +      DC      16
00BD 0  0000       143   +      DC      0
00BE 0  203A       144   +      DC      8250
00BF 0  0001       145   +      DC      1
00C0 0  0080       146   +      DC      128
00C1 0  C033       147   TMAX   LD      =16500                  HWS00300
00C2 0  921E       148          S    2  VT157                   HWS00310
00C3 01 4C3000CD   149          BP      TIN1                    HWS00320
00C5 0  C030       150          LD      =3                      HWS00330
00C6 0  D0F4       151          STO     NIN                     HWS00340
00C7 0  C0F5       152          LD      =0                      HWS00350
00C8 0  D0F0       153          STO     C1                      HWS00360
00C9 0  C0F6       154          LD      =128
00CA 0  D0EF       155          STO     C2                      HWS00380
00CB 01 4C000180   156          B    L  IN3F                    HWS00390
00CD 0  C029       157   TIN1   LD      =11550                  HWS00400
00CE 0  921E       158          S    2  VT157                   HWS00410
00CF 01 4C280008   159          BN      TIN2                    HWS00420
00D1 0  1889       160          SRT     9
00D2 0  A825       161          D       =3300                   HWS00440
00D3 0  D0E5       162          STO     C1                      HWS00450
00D4 0  C0E8       163          LD      =128
00D5 0  90E3       164          S       C1                      HWS00470
```

Table B-11. Honeywell Control Program (Continued)


```
00D6 0  D0E3       165               STO      C2                              HWS00480
00D7 0  C0E7       166               LD       =1                              HWS00490
00D8 0  D0E2       167               STO      NIN                             HWS00500
00D9 01 4C000114   168               B     L  IN1F                            HWS00510
00DB 0  C01D       169        TIN2   LD       =14025                          HWS00520
00DC 0  921E       170               S      2 VT157                           HWS00530
00DD 01 4C2800E9   171               BN       TIN3                            HWS00540
00DF 0  1889       172               SRT      9
00E0 0  A819       173               D        =2475                           HWS00560
00E1 0  D0D7       174               STO      C1                              HWS00570
00E2 0  C0D0       175               LD       =128
00E3 0  90D5       176               S        C1                              HWS00590
00E4 0  D0D5       177               STO      C2                              HWS00600
00E5 0  C015       178               LD       =2                              HWS00610
00E6 0  D0D4       179               STO      NIN                             HWS00620
00E7 01 4C00014A   180               B     L  IN2F                            HWS00630
00E9 0  C008       181        TIN3   LD       =16500                          HWS00640
00EA 0  921E       182               S      2 VT157                           HWS00650
00EB 0  1889       183               SRT      9
00EC 0  A80D       184               D        =2475                           HWS00670
00ED 0  D0CB       185               STO      C1                              HWS00680
00EE 0  C0D1       186               LD       =128
00EF 0  90C9       187               S        C1                              HWS00700
00F0 0  D0C9       188               STO      C2                              HWS00710
00F1 0  C004       189               LD       =3                              HWS00720
00F2 0  D0C8       190               STO      NIN                             HWS00730
00F3 01 4C000180   191               B     L  IN3F                            HWS00740
                   192               LORG                                     HWS00750
00F5 0  4074       193        +      DC       16500
00F6 0  0003       194        +      DC       3
00F7 0  2D1E       195        +      DC       11550
00F8 0  0CE4       196        +      DC       3300
00F9 0  36C9       197        +      DC       14025
00FA 0  09AB       198        +      DC       2475
00FB 0  0002       199        +      DC       2
                   200        *     EQULIBRIUM FUEL FLOW 50 GAINS             HWS00760
00FC 0  0000       201        KEF11  DC       *-*
00FD 0  0000       202        KEF12  DC       0
00FE 0  0000       203        KEF13  DC       0
00FF 0  0000       204        KEF14  DC       *-*
0100 0  0000       205        WEF1   DC       *-*
0101 0  0A91       206        P3E1   DC       2705
0102 0  0661       207        P5E1   DC       1633
                   208        *     TEMPERATURE FUEL FLOW 50 GAINS            HWS00920
0103 0  0000       209        KTF11  DC       *-*
0104 0  0000       210        KTF12  DC       *-*
0105 0  0000       211        KTF13  DC       *-*
0106 0  0000       212        KTF14  DC       *-*
0107 0  0000       213        HTF1   DC       *-*
0108 0  0000       214        P3T1   DC       *-*
0109 0  0000       215        P5T1   DC       *-*
010A 0  0000       216        TB1    DC       *-*
010B 0  028A       217        WFMN1  DC       650
010C 0  0001       218        BUMP1  DC       1                               HWS00980
010D 0  0000       219        SETX1  DC       0                               HWS00990
010E 0  0010       220        NGFT   DC       16
010F 0  0000       221        C11    DC       *-*                             HWS01010
```

Table B-11. Honeywell Control Program (Continued)


```
0110 0  0000          C21    DC        *-*                    HWS01020
0111 0  0000          TST1   DC        *-*                    HWS01040
0112    0000          SUM1   BSS   E   0
0112 0  0000                 DC        0
0113 0  0000                 DC        0
0114                  IN1F   EQU       *                      HWS01050
0114 01 C40000B9             LD    L   C1                     HWS01060
0116 0  D0F8                 STO       C11                    HWS01070
0117 01 C40000BA             LD    L   C2                     HWS01080
0119 0  D0F6                 STO       C21                    HWS01090
011A 01 C400010D             LD    L   SETX1                  HWS01100
011C 0  D0F4                 STO       TST1                   HWS01110
011D 01 65800111      LUP1   LDX   I1  TST1                   HWS01120
011F 01 C50000FC             LD    L1  KEF11                  HWS01130
0121 0  A0ED                 M         C11                    HWS01140
0122 0  D8EF                 STD       SUM1
0123 01 C5000135             LD    L1  KEF21                  HWS01170
0125 0  A0EA                 M         C21                    HWS01180
0126 0  88E8                 AD        SUM1
0127 0  1887                 SRT       7
0128 0  1090                 SLT       16
0129 01 D5000406             STO   L1  KEFN1                  HWS01220
012B 0  C0E5                 LD        TST1                   HWS01230
012C 01 8400010C             A     L   BUMP1                  HWS01240
012E 0  D0E2                 STO       TST1                   HWS01250
012F 01 9400010E             S     L   NGFT                   HWS01260
0131 01 4C28011D             BN        LUP1                   HWS01270
0133 01 4C0001B1             B     L   FUELM                  HWS01280
                      *    EQUILIBRIUM FUEL FLOW 70 GAINS     HWS01290
0135 0  0000          KEF21  DC        *-*
0136 0  0000          KEF22  DC        0
0137 0  0000          KEF23  DC        0
0138 0  0000          KEF24  DC        *-*
0139 0  0000          WEF2   DC        *-*
013A 0  1109          P3E2   DC        4361
013B 0  0765          P5E2   DC        1893
                      *    TEMPERATURE FUEL FLOW 70 GAINS     HWS01450
013C 0  0000          KTF21  DC        *-*
013D 0  0000          KTF22  DC        *-*
013E 0  0000          KTF23  DC        *-*
013F 0  0000          KTF24  DC        *-*
0140 0  0000          WTF2   DC        *-*
0141 0  0000          P3T2   DC        *-*
0142 0  0000          P5T2   DC        *-*
0143 0  0000          TB2    DC        *-*
0144 0  0472          WFMN2  DC        1138
0145 0  0000          C12    DC        *-*                    HWS01510
0146 0  0000          C22    DC        *-*                    HWS01520
0147 0  0000          TST2   DC        *-*                    HWS01540
0148    0000          SUM2   BSS   E   0
0148 0  0000                 DC        0
0149 0  0000                 DC        0
014A                  IN2F   EQU       *                      HWS01550
014A 01 C40000B9             LD    L   C1                     HWS01560
014C 0  D0F8                 STO       C12                    HWS01570
014D 01 C40000BA             LD    L   C2                     HWS01580
014F 0  D0F6                 STO       C22                    HWS01590
```

Table B-11. Honeywell Control Program (Continued)


```
0150 01 C400010D        LD    L  SETX1                              HWS01600
0152 0  D0F4            STO      TST2                               HWS01610
0153 01 65800147  LUP2  LDX   I1 TST2                               HWS01620
0155 01 C5000135        LD    L1 KEF21                              HWS01630
0157 0  A0ED            M        C12                                HWS01640
0158 0  D8EF            STD      SUM2
0159 01 C5000168        LD    L1 KEF31                              HWS01670
015B 0  A0EA            M        C22                                HWS01680
015C 0  88EB            AD       SUM2
015D 0  1887            SRT      7
015E 0  1090            SLT      16
015F 01 D5000406        STO   L1 KEFN1                              HWS01720
0161 0  C0E5            LD       TST2                               HWS01730
0162 01 8400010C        A     L  BUMP1                              HWS01740
0164 0  D0E2            STO      TST2                               HWS01750
0165 01 9400010E        S     L  NGFT                               HWS01760
0167 01 4C280153        BN       LUP2                               HWS01770
0169 01 4C0001B1        B     L  FUELM                              HWS01780
                  *       EQUILIBRIUM FUEL FLOW 85 GAINS            HWS01790
016B 0  0000      KEF31 DC       *-*
016C 0  0000      KEF32 DC       0
016D 0  0000      KEF33 DC       0
016E 0  0000      KEF34 DC       *-*
016F 0  0000      WEF3  DC       *-*
0170 0  1811      P3E3  DC       6161
0171 0  08C3      P5E3  DC       2243
                  *       TEMPERATURE FUEL FLOW 85 GAINS            HWS01950
0172 0  0000      KTF31 DC       *-*
0173 0  0000      KTF32 DC       *-*
0174 0  0000      KTF33 DC       *-*
0175 0  0000      KTF34 DC       *-*
0176 0  0000      WTF3  DC       *-*
0177 0  0000      P3T3  DC       *-*
0178 0  0000      P5T3  DC       *-*
0179 0  0000      TB3   DC       *-*
017A 0  0659      WFMN3 DC       1625
017B 0  0000      C13   DC       *-*                                HWS02010
017C 0  0000      C23   DC       *-*                                HWS02020
017D 0  0000      TST3  DC       *-*                                HWS02040
017E    0000      SUM3  BSS   E  0
017E 0  0000            DC       0
017F 0  0000            DC       0
0180              IN3F  EQU      *                                  HWS02050
0180 01 C4000089        LD    L  C1                                 HWS02060
0182 0  D0F8            STO      C13                                HWS02070
0183 01 C40000BA        LD    L  C2                                 HWS02080
0185 0  D0F6            STO      C23                                HWS02090
0186 01 C400010D        LD    L  SETX1                              HWS02100
0188 0  D0F4            STO      TST3                               HWS02110
0189 01 6580017D  LUP3  LDX   I1 TST3                               HWS02120
018B 01 C500016B        LD    L1 KEF31                              HWS02130
018D 0  A0ED            M        C13                                HWS02140
018E 0  D8EF            STD      SUM3
018F 01 C50001A1        LD    L1 KEF41                              HWS02170
0191 0  A0EA            M        C23                                HWS02180
0192 0  88EB            AD       SUM3
0193 0  1887            SRT      7
```

Table B-11. Honeywell Control Program (Continued)


```
0194 0  1090           SLT      15
0195 01 D5000406       STO  L1  KEFN1                        HWS02220
0197 0  C0E5           LD       TST3                         HWS02230
C198 01 8400010C       A    L   BUMP1                        HWS02240
019A 0  D0E2           STO      TST3                         HWS02250
019B 01 9400010E       S    L   NGFT                         HWS02260
019D 01 4C280189       BN       LUP3                         HWS02270
019F 01 4C0001B1       B    L   FUELM                        HWS02280
                *      EQUILIBRIUM FUEL FLOW 100 GAINS       HWS02290
01A1 0  0000    KEF41  DC       *-*
01A2 0  0000    KEF42  DC       0
01A3 0  0000    KEF43  DC       0
01A4 0  0000    KEF44  DC       *-*
01A5 0  0000    WEF4   DC       *-*
01A6 0  277E    P3E4   DC       10110
01A7 0  0F94    P5E4   DC       3988
                *      TEMPERATURE FUEL FLOW 100 GAINS       HWS02450
01A8 0  0000    KTF41  DC       *-*
01A9 0  0000    KTF42  DC       *-*
01AA 0  0000    KTF43  DC       *-*
01AB 0  0000    KTF44  DC       *-*
01AC 0  0000    WTF4   DC       *-*
01AD 0  0000    P3T4   DC       *-*
01AE 0  0000    P5T4   DC       *-*
01AF 0  0000    T84    DC       *-*
01B0 0  0CB2    WFMN4  DC       3250
01B1            FUELM  EQU      *                            HWS02510
01B1            FT4W   EQU      *
01B1 0  C29A           LD   2   VT102      LOAD PBX100
01B2 0  9032           S        =5850
01B3 01 4C3001CD       BP       NEXT
01B5 0  C030           LD       =1553
01B6 0  A030           M        =100
01B7 01 DC0001F2       STD  L   TMPF
01B9 0  C29A           LD   2   VT102
01BA 0  A02D           M        =6
01BB 01 8C0001F2       AD   L   TMPF
01BD 0  A82B           D        =3400
01BF 01 D40001FB       STO  L   K1THD
01C0 0  C29A           LD   2   VT102
01C1 0  A028           M        =200
01C2 01 DC0001F2       STD  L   TMPF
01C4 0  C026           LD       =15100
01C5 0  A021           M        =100
01C6 01 9C0001F2       SD   L   TMPF
01C8 0  A820           D        =3400
01C9 01 D40001FC       STO  L   TAU2T
01CB 01 4C0001E3       B    L   FT4WC
01CD 0  C01E    NEXT   LD       =2202
01CE 0  A01B           M        =100
01CF 01 DC0001F2       STD  L   TMPF
01D1 0  C29A           LD   2   VT102
01D2 0  A01A           M        =4
01D3 01 8C0001F2       AD   L   TMPF
01D5 0  A818           D        =4350
01D6 01 D40001FB       STO  L   K1THD
01D8 0  C29A           LD   2   VT102
```

Table B-11. Honeywell Control Program (Continued)


```
01D9 0  A015       393           M       =20
01DA 01 DC0001F2   394           STD  L  TMPF
01DC 0  C013       395           LD      =5520
01DD 0  A009       396           M       =100
01DE 01 9C0001F2   397           SD   L  TMPF
01E0 0  A80D       398           D       =4350
01E1 01 D40001FC   399           STD  L  TAU2T
01E3 01 4C0001FE   400    FT4WC  B    L  STP1
                   401           LORG
01E5 0  16DA       402    +      DC      5850
01E6 0  0611       403    +      DC      1553
01E7 0  0064       404    +      DC      100
01E8 0  0006       405    +      DC      6
01E9 0  0D48       406    +      DC      3400
01EA 0  00C8       407    +      DC      200
01EB 0  3AFC       408    +      DC      15100
01EC 0  089A       409    +      DC      2202
01ED 0  0004       410    +      DC      4
01EE 0  10FE       411    +      DC      4350
01EF 0  0014       412    +      DC      20
01F0 0  1590       413    +      DC      5520
01F2    0000       414    TMPF   BSS  E  0
01F2 0  0000       415           DC      0
01F3 0  0000       416           DC      0
01F4    0000       417    XT4    BSS  E  0
01F4 0  0000       418           DC      0
01F5 0  0000       419           DC      0
01F6    0000       420    XT4D   BSS  E  0
01F6 0  0000       421           DC      0
01F7 0  0000       422           DC      0
01F8    0000       423    XT4D1  BSS  E  0
01F8 0  0000       424           DC      0
01F9 0  0000       425           DC      0
01FA 0  0000       426    T4WF   DC      *-*
01FB 0  0000       427    K1THD  DC      *-*
01FC 0  0000       428    TAU2T  DC      *-*
01FD 0  0000       429    ISW    DC      0
01FE 01 C4000280   430    STP1   LD   L  =1234
0200 0  90FC       431           S       ISW
0201 01 4C18020E   432           BZ      STP2
0203 0  D0F9       433           STO     ISW
0204 01 C400008D   434           LD   L  =0
0206 0  1890       435           SRT     16
0207 0  D8EE       436           STD     XT4D
0208 0  D8EF       437           STD     XT4D1
0209 0  C29F       438           LD    2 VT097
020A 0  1890       439           SRT     16
020B 0  D0E8       440           STO     XT4
020C 01 4C000219   441           B    L  STP3
020E 01 C400008D   442    STP2   LD   L  =0
0210 0  1890       443           SRT     16
0211 0  C29F       444           LD    2 VT097
0212 0  1890       445           SRT     16
0213 0  98E0       446           SD      XT4
0214 0  A3E6       447           D       K1THD
0215 0  A0D1       448           M       =100
0216 0  A8E5       449           D       TAU2T
```

Table B-11. Honeywell Control Program (Continued)


```
0217 0  A069        450          M        =10
0218 0  D8DD        451          STD      XT4D
0219 0  C8DC        452   STP3   LDD      XT4D         *** UPDATE D E  ***
021A 0  88DD        453          AD       XT4D1
021B 0  A866        454          D        =50
021C 01 A400028E    455          M     L  DT
021E 0  A864        456          D        =40
021F 0  1890        457          SRT      16
0220 0  88D3        458          AD       XT4
0221 0  D8D2        459          STD      XT4
0222 0  D2B0        460          STO    2 VT080        *** MOST SIGNIFICANT PART
0223 0  1090        461          SLT      16               OF XT4
0224 0  D2A6        462          STO    2 VT090            LEAST SIGNIFICANT PART
0225 0  C8D0        463          LDD      XT4D
0226 0  D8D1        464          STD      XT4D1        *** CALCULATE T4WF ***
0227 0  A859        465          D        =10
0228 0  A0D3        466          M        TAU2T
0229 0  88CA        467          AD       XT4
022A 0  1090        468          SLT      16
022B 0  D0CE        469          STO      T4WF
022C 0  D24C        470          STO    2 VT203
022D 0  C2D9        471          LD     2 VT039                        HWS02520
022E 0  9055        472          S        =64                         HWS02530
022F 01 4C20024B    473          BNZ      MDW9                        HWS02540
0231 0  D2D9        474          STO    2 VT039
0232 0  C20C        475          LD     2 VT036                        HWS02550
0233 0  D05B        476          STO      ENK
0234 01 4C100238    477          BNN      SENL
0236 0  C04E        478          LD       =0
0237 0  9057        479          S        ENK
0238 0  D057        480   SENL   STO      ENKL
0239 0  C2DB        481          LD     2 VT037                        HWS02570
023A 0  1884        482          SRT      4
023B 0  D055        483          STO      EPK
023C 01 4C100240    484          BNN      SEPL
023E 0  C046        485          LD       =0
023F 0  9051        486          S        EPK
0240 0  D051        487   SEPL   STO      EPKL
0241 0  C2DA        488          LD     2 VT038                        HWS02590
0242 01 D4000293    489          STO   L  ETK
0244 01 4C100249    490          BNN      SETL
0246 0  C03E        491          LD       =0
0247 01 94000293    492          S     L  ETK
0249 01 D4000294    493   SETL   STO   L  ETKL
024B                494   MDW9   EQU      *                           HWS02610
                    495   *                                           HWS02620
                    496   *                                           HWS02630
                    497   *                                           HWS02640
                    498   *                                           HWS02650
                    499   *      THIS SECTION OF THE PROGRAM          HWS02660
                    500   *      WILL SET UP THE MEASUREMENT FEED-BACK HWS02670
                    501   *      VECTOR FOR THE THREE CONTROLLERS     HWS02680
                    502   *      EQUILIBRIUM,PRESSURE,TEMPERATURE     HWS02690
                    503   *                                           HWS02700
                    504   *                                           HWS02710
                    505   *                                           HWS02720
                    506   * CALCULATE DERIVATIVES FOR EN EP ET        HWS02730
```

Table B-11. Honeywell Control Program (Continued)


```
                     *                                                     HWS02740
024B 0  C201                LD    2 VT128                                  HWS02750
024C 0  921E                S     2 VT157                                  HWS02760
024D 0  D03A                STO     ENDK                                   HWS02770
024E 01 C4000412            LD    L P3TNB
0250 0  929A                S     2 VT102
0251 0  D038                STO     EPDK                                   HWS02840
0252 01 C4000414            LD    L TBBN      *** CALCULATE ETDOT ***
0254 0  90A5                S       T4WF
0255 01 D400028C            STO   L ETDK
0257 0  C02F                LD      TIME                                   HWS02900
0258 01 4C200295            BNZ     INTEG                                  HWS02910
025A 01 C400046A            LD    L ONE
025C 0  D2B6                STO   2 VT074
025D 0  C02A                LD      ENDK                                   HWS02920
025E 0  D02A                STO     ENDK1                                  HWS02930
025F 0  C02A                LD      EPDK                                   HWS02940
0260 0  D02A                STO     EPDK1                                  HWS02950
0261 0  C02A                LD      ETDK                                   HWS02960
0262 0  D02A                STO     ETDK1                                  HWS02970
0263 0  C20C                LD    2 VT036                                  HWS02980
0264 0  D02A                STO     ENK                                    HWS02990
0265 01 4C100269            BNN     STENL
0267 0  C01D                LD      =0
0268 0  9026                S       ENK
0269 0  D026         STENL  STO     ENKL
026A 0  C2DD                LD    2 VT037                                  HWS03010
026B 0  1884                SRT     4
026C 0  D024                STO     EPK                                    HWS03030
026D 01 4C100271            BNN     STEPL
026F 0  C015                LD      =0
0270 0  9020                S       EPK
0271 0  D020         STEPL  STO     EPKL
0272 0  C2DA                LD    2 VT038                                  HWS03050
0273 01 D4000293            STO   L ETK
0275 01 4C10027A            BNN     STETL
0277 0  C00D                LD      =0
0278 01 94000293            S     L ETK
027A 01 D4000294     STETL  STO   L ETKL
027C 0  C009                LD      =1                                     HWS03080
027D 0  D009                STO     TIME                                   HWS03090
027E 01 4C000295            B     L INTEG
                            LORG                                           HWS03110
0280 0  04D2         +      DC      1234
0281 0  000A         +      DC      10
0282 0  0032         +      DC      50
0283 0  0028         +      DC      40
0284 0  0040         +      DC      64
0285 0  0000         +      DC      0
0286 0  0001         +      DC      1
                     *GENERATE EN EP ET                                    HWS03120
0287 0  0000         TIME   DC      0
0288 0  0000         ENDK   DC      *-*                                    HWS03140
0289 0  0000         ENDK1  DC      *-*                                    HWS03150
028A 0  0000         EPDK   DC      *-*                                    HWS03160
028B 0  0000         EPDK1  DC      *-*                                    HWS03170
028C 0  0000         ETDK   DC      *-*                                    HWS03180
```

Table B-11. Honeywell Control Program (Continued)


```
028D 0  0000         564   ETDK1 DC        *-*                                HWS03190
028E 0  000F         565   DT    DC        15                                 HWS03200
028F 0  0000         566   ENK   DC        *-*                                HWS03210
0290 0  0000         567   ENKL  DC        *-*                                HWS03220
0291 0  0000         568   EPK   DC        *-*                                HWS03230
0292 0  0000         569   EPKL  DC        *-*                                HWS03240
0293 0  0000         570   ETK   DC        *-*                                HWS03250
0294 0  0000         571   ETKL  DC        *-*                                HWS03260
                     572   *                                                  HWS03280
0295                 573   INTEG EQU       *                                  HWS03290
                     574   *                    CALCULATE EN                  HWS03300
0295 0  C0F2         575         LD        ENDK
0296 0  80F2         576         A         ENDK1
0297 0  A0F6         577         M         DT
0298 0  1083         578         SLT       3
0299 0  A84F         579         D         =375
029A 0  80F4         580         A         ENK                                HWS03400
029B 0  D0F3         581         STO       ENK                                HWS03410
029C 0  C2B6         582         LD      2 VT074
029D 01 9400046A     583         S       L ONE
029F 01 4C1802A3     584         BZ        NM1
02A1 0  C0E3         585         LD        =0
02A2 0  D0EC         586         STO       ENK
                     587   *                    CALCULATE EP                  HWS03420
                     588   *                    CALCULATE ET                  HWS03510
02A3 01 C400028C     589   NM1   LD      L ETDK
02A5 01 8400028D     590         A       L ETDK1
02A7 01 A400028E     591         M       L DT
02A9 0  1084         592         SLT       4           *** SCALE FACTOR 16 ***
02AA 0  A83F         593         D         =1500
02AB 0  80E7         594         A         ETK
02AC 0  D0E6         595         STO       ETK
02AD 0  C2B6         596         LD      2 VT074
02AE 01 9400046B     597         S       L TWO
02B0 01 4C1802B4     598         BZ        NM2
02B2 0  C0D2         599         LD        =0
02B3 0  D0DF         600         STO       ETK
                     601   *                    LIMLTS ON EN EP ET            HWS03600
02B4 0  C0DA         602   NM2   LD        ENK
02B5 01 4C2802BE     603         BN        MW1                                HWS03620
02B7 0  90D8         604         S         ENKL                               HWS03630
02B8 01 4C0802C5     605         BNP       MW2                                HWS03640
02BA 0  C0D5         606         LD        ENKL                               HWS03650
02BB 0  D0D3         607         STO       ENK                                HWS03660
02BC 01 4C0002C5     608         B       L MW2                                HWS03670
02BE                 609   MW1   EQU       *                                  HWS03680
02BE 0  C0D0         610         LD        ENK                                HWS03690
02BF 0  80D0         611         A         ENKL                               HWS03700
02C0 01 4C3002C5     612         BP        MW2                                HWS03710
02C2 0  C0C2         613         LD        =0                                 HWS03720
02C3 0  90CC         614         S         ENKL                               HWS03730
02C4 0  D0CA         615         STO       ENK                                HWS03740
02C5                 616   MW2   EQU       *                                  HWS03750
02C5 0  C0CB         617         LD        EPK                                HWS03760
02C6 01 4C2802CF     618         BN        MW3                                HWS03770
02C8 0  90C9         619         S         EPKL                               HWS03780
02C9 01 4C0802D6     620         BNP       MW4                                HWS03790
```

Table B-11. Honeywell Control Program (Continued)

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```
02CB 0  C0C6       621          LD        EPKL                                HWS03800
02CC 0  D0C4       622          STO       EPK                                 HWS03810
02CD 01 4C0002D6   623          B     L   MW4                                 HWS03820
02CF               624   MW3    EQU       *                                   HWS03830
02CF 0  C0C1       625          LD        EPK                                 HWS03840
02D0 0  80C1       626          A         EPKL                                HWS03850
02D1 01 4C3002D6   627          BP        MW4                                 HWS03860
02D3 0  C0B1       628          LD        =0                                  HWS03870
02D4 0  90BD       629          S         EPKL                                HWS03880
02D5 0  D0BB       630          STO       EPK                                 HWS03890
02D6               631   MW4    EQU       *                                   HWS03900
02D6 0  C0BC       632          LD        ETK                                 HWS03910
02D7 01 4C2802E0   633          BN        MW5                                 HWS03920
02D9 0  90BA       634          S         ETKL                                HWS03930
02DA 01 4C0802EB   635          BNP       MW6                                 HWS03940
02DC 0  C0B7       636          LD        ETKL                                HWS03950
02DD 0  D0B5       637          STO       ETK                                 HWS03960
02DE 01 4C0002EB   638          B     L   MW6                                 HWS03970
02E0               639   MW5    EQU       *                                   HWS03980
02E0 0  C0B2       640          LD        ETK                                 HWS03990
02E1 0  80B2       641          A         ETKL                                HWS04000
02E2 01 4C3002EB   642          BP        MW6                                 HWS04010
02E4 0  C0A0       643          LD        =0                                  HWS04020
02E5 0  90AE       644          S         ETKL                                HWS04030
02E6 0  D0AC       645          STO       ETK                                 HWS04040
02E7 01 4C0002EB   646          B     L   MW6                                 HWS04050
                   647          LORG                                          HWS04060
02E9 0  0177       648   +      DC        375
02EA 0  05DC       649   +      DC        1500
                   650   *                   AGE DERIVATIVES                  HWS04070
02EB               651   MW6    EQU       *                                   HWS04080
02EB 01 C4000288   652          LD    L   ENDK                                HWS04090
02ED 01 D4000289   653          STO   L   ENDK1                               HWS04100
02EF 01 C400028A   654          LD    L   EPDK                                HWS04110
02F1 01 D400028B   655          STO   L   EPDK1                               HWS04120
02F3 01 C400028C   656          LD    L   ETDK                                HWS04130
02F5 01 D400028D   657          STO   L   ETDK1                               HWS04140
                   658   *                                                    HWS04150
                   659   *                INTERPOLATE FOR PT3 AND PT5         HWS04160
                   660   *                AS A FUNCTION OF PLA                HWS04170
02F7               661   PLA    EQU       *
02F7 0  C066       662          LD        NPL1                                HWS04180
02F8 0  9201       663          S     2   VT128                               HWS04190
02F9 01 4C280309   664          BN        MDW1                                HWS04200
02FB 01 C4000101   665          LD    L   P3E1                                HWS04210
02FD 01 D4000408   666          STO   L   P3PL                                HWS04220
02FF 01 C4000102   667          LD    L   P5E1                                HWS04230
0301 01 D400040C   668          STO   L   P5PL                                HWS04240
0303 01 C4000100   669          LD    L   WEF1                                HWS04250
0305 01 D400040A   670          STO   L   WEFN                                HWS04260
0307 01 4C0003A7   671          B     L   MDW6                                HWS04270
0309 0  C057       672   MDW1   LD        NPL4                                HWS04280
030A 0  9201       673          S     2   VT128                               HWS04290
030B 01 4C300318   674          BP        MDW2                                HWS04300
030D 01 C40001A6   675          LD    L   P3E4                                HWS04310
030F 01 D4000408   676          STO   L   P3PL                                HWS04320
0311 01 C40001A7   677          LD    L   P5E4                                HWS04330
```

Table B-11. Honeywell Control Program (Continued)


```
0313 01 D400040C    678          STO  L   P5PL         HWS04340
0315 01 C40001A5    679          LD   L   WEF4         HWS04350
0317 01 D400040A    680          STO  L   WEFN         HWS04360
0319 01 4C0003A7    681          B    L   MDW6         HWS04370
031B 01 C400035F    682   MDW2   LD   L   NPL2         HWS04380
031D 0  9201        683          S      2 VT128        HWS04390
031E 01 4C28033E    684          BN       MDW3         HWS04400
0320 0  1889        685          SRT      9
0321 0  A81A        686          D        =3300        HWS04420
0322 0  D03F        687          STO      CX1          HWS04430
0323 0  C019        688          LD       =128
0324 0  903D        689          S        CX1          HWS04450
0325 0  D03D        690          STO      CX2          HWS04460
0326 01 C4000101    691          LD   L   P3E1         HWS04470
0328 0  D03B        692          STO      P3L          HWS04480
0329 01 C400013A    693          LD   L   P3E2         HWS04490
032B 0  D039        694          STO      P3M          HWS04500
032C 01 C4000102    695          LD   L   P5E1         HWS04510
032E 0  D037        696          STO      P5L          HWS04520
032F 01 C400013B    697          LD   L   P5E2         HWS04530
0331 0  D035        698          STO      P5M          HWS04540
0332 01 C4000100    699          LD   L   WEF1         HWS04550
0334 01 D4000368    700          STO  L   WEFL         HWS04560
0336 01 C4000139    701          LD   L   WEF2         HWS04570
0338 01 D4000369    702          STO  L   WEFM         HWS04580
033A 01 4C000388    703          B    L   MDW5         HWS04590
                    704          LORG                  HWS04600
033C 0  0CE4        705   +      DC       3300
033D 0  0080        706   +      DC       128
033E 0  C021        707   MDW3   LD       NPL3         HWS04610
033F 0  9201        708          S      2 VT128        HWS04620
0340 01 4C28036C    709          BN       MDW4         HWS04630
0342 0  1889        710          SRT      9
0343 0  A862        711          D        =2475        HWS04650
0344 0  D01D        712          STO      CX1          HWS04660
0345 0  C0F7        713          LD       =128
0346 0  901B        714          S        CX1          HWS04680
0347 0  D01B        715          STO      CX2          HWS04690
0348 01 C400013A    716          LD   L   P3E2         HWS04700
034A 0  D019        717          STO      P3L          HWS04710
034B 01 C4000170    718          LD   L   P3E3         HWS04720
034D 0  D017        719          STO      P3M          HWS04730
034E 01 C400013B    720          LD   L   P5E2         HWS04740
0350 0  D015        721          STO      P5L          HWS04750
0351 01 C4000171    722          LD   L   P5E3         HWS04760
0353 0  D013        723          STO      P5M          HWS04770
0354 01 C4000139    724          LD   L   WEF2         HWS04780
0356 01 D4000368    725          STO  L   WEFL         HWS04790
0358 01 C400016F    726          LD   L   WEF3         HWS04800
035A 01 D4000369    727          STO  L   WEFM         HWS04810
035C 01 4C000388    728          B    L   MDW5         HWS04820
035E 0  203A        729   NPL1   DC       8250         HWS04830
035F 0  2D1E        730   NPL2   DC       11550        HWS04840
0360 0  36C9        731   NPL3   DC       14025        HWS04850
0361 0  4074        732   NPL4   DC       16500        HWS04860
0362 0  0000        733   CX1    DC       *-*          HWS04870
0363 0  0000        734   CX2    DC       *-*          HWS04880
```

Table B-11. Honeywell Control Program (Continued)

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0364	0	0000	735	P3L	DC		*-*	HWS04890
0365	0	0000	736	P3M	DC		*-*	HWS04900
0366	0	0000	737	P5L	DC		*-*	HWS04910
0367	0	0000	738	P5M	DC		*-*	HWS04920
0368	0	0000	739	WEFL	DC		*-*	HWS04940
0369	0	0000	740	WEFM	DC		*-*	HWS04950
036A		0000	741	SUMX	BSS	E	0	
036A	0	0000	742		DC		0	
036B	0	0000	743		DC		0	
036C	0	C0F4	744	MDW4	LD		NPL4	HWS04960
036D	0	9201	745		S	2	VT128	HWS04970
036E	0	1889	746		SRT		9	
036F	0	A836	747		D		=2475	HWS04990
0370	0	D0F1	748		STO		CX1	HWS05000
0371	0	C0CB	749		LD		=128	
0372	0	90EF	750		S		CX1	HWS05020
0373	0	D0EF	751		STO		CX2	HWS05030
0374	01	C4000170	752		LD	L	P3E3	HWS05040
0376	0	D0ED	753		STO		P3L	HWS05050
0377	01	C40001A6	754		LD	L	P3E4	HWS05060
0379	0	D0EB	755		STO		P3M	HWS05070
037A	01	C4000171	756		LD	L	P5E3	HWS05080
037C	0	D0E9	757		STO		P5L	HWS05090
037D	01	C40001A7	758		LD	L	P5E4	HWS05100
037F	0	D0E7	759		STO		P5M	HWS05110
0380	01	C400016F	760		LD	L	WEF3	HWS05120
0382	01	D4000368	761		STO	L	WEFL	HWS05130
0384	01	C40001A5	762		LD	L	WEF4	HWS05140
0386	01	D4000369	763		STO	L	WEFM	HWS05150
0388	0	C0DB	764	MDW5	LD		P3L	HWS05160
0389	0	A0D8	765		M		CX1	HWS05170
038A	0	D8DF	766		STD		SUMX	
038B	0	C0D9	767		LD		P3M	HWS05200
038C	0	A0D6	768		M		CX2	HWS05210
038D	0	88DC	769		AD		SUMX	
038E	0	1887	770		SRT		7	
038F	0	1090	771		SLT		16	
0390	0	D07A	772		STO		P3PL	HWS05250
0391	0	C0D4	773		LD		P5L	HWS05260
0392	0	A0CF	774		M		CX1	HWS05270
0393	0	D8D6	775		STD		SUMX	
0394	0	C0D2	776		LD		P5M	HWS05300
0395	0	A0CD	777		M		CX2	HWS05310
0396	0	88D3	778		AD		SUMX	
0397	0	1887	779		SRT		7	
0398	0	1090	780		SLT		16	
0399	0	D072	781		STO		P5PL	HWS05350
039A	01	C4000368	782		LD	L	WEFL	HWS05360
039C	0	A0C5	783		M		CX1	HWS05370
039D	0	D8CC	784		STD		SUMX	
039E	0	C0CA	785		LD		WEFM	HWS05400
039F	0	A0C3	786		M		CX2	HWS05410
03A0	0	88C9	787		AD		SUMX	
03A1	0	1887	788		SRT		7	
03A2	0	1090	789		SLT		16	
03A3	0	D066	790		STO		WEFN	HWS05450
03A4	01	4C0003A7	791		B	L	MDW6	HWS05460

Table B-11. Honeywell Control Program (Continued)


```
                         792          LORG                                          HWS05470
03A6 0  09AB             793   +      DC        2475
03A7                     794   MDW6   EQU       *                                   HWS05510
03A7 01 C400040C         795          LD     L  P5PL                                HWS05520
0349 0  D223             796          STO    2  VT162                               HWS05530
03AA 01 C400040B         797          LD     L  P3PL                                HWS05540
03AC 0  D224             798          STO    2  VT163                               HWS05550
03AD 01 C400028F         799          LD     L  ENK                                 HWS05560
03AF 0  D225             800          STO    2  VT164                               HWS05570
03B0 01 C400040A         801          LD     L  WEFN                                HWS05580
03B2 0  D226             802          STO    2  VT165                               HWS05590
03B3 01 C4000406         803          LD     L  KEFN1                               HWS05600
03B5 0  D227             804          STO    2  VT166                               HWS05610
03B6 01 C4000407         805          LD     L  KEFN2                               HWS05620
03B8 0  D228             806          STO    2  VT167                               HWS05630
03B9 01 C4000411         807          LD     L  WTFN
03BB 0  D229             808          STO    2  VT168                               HWS05650
03BC 01 C4000409         809          LD     L  KEFN4                               HWS05660
03BE 0  D22A             810          STO    2  VT169                               HWS05670
03BF 01 C4000413         811          LD     L  P5TNB
03C1 0  D22B             812          STO    2  VT170                               HWS05690
03C2 01 C4000412         813          LD     L  P3TNB
03C4 0  D22C             814          STO    2  VT171                               HWS05710
03C5 01 C4000293         815          LD     L  ETK
03C7 0  D22D             816          STO    2  VT172                               HWS05730
03C8 01 C400040D         817          LD     L  KTFN1
03CA 0  D22E             818          STO    2  VT173                               HWS05750
03CB 01 C400040E         819          LD     L  KTFN2
03CD 0  D22F             820          STO    2  VT174                               HWS05770
03CE 01 C400040F         821          LD     L  KTFN3
03D0 0  D230             822          STO    2  VT175                               HWS05790
03D1 01 C4000410         823          LD     L  KTFN4
03D3 0  D231             824          STO    2  VT176                               HWS05810
03D4 01 C4000414         825          LD     L  TBBN
03D6 0  D24B             826          STO    2  VT202
                         827   *                                                    HWS05480
                         828   *     CALCULATE X-XO  FOR EQUILIBRIUM PRESSURE       HWS05490
                         829   *                                                    HWS05500
03D7                     830   MEPT   EQU       *
03D7 0  C21E             831          LD     2  VT157                               HWS05820
03D8 0  9201             832          S      2  VT128                               HWS05830
03D9 0  D024             833          STO       ME1                                 HWS05840
03DA 0  D245             834          STO    2  VT196
03DB 0  C294             835          LD     2  VT108                               HWS05850
03DC 01 9400040C         836          S      L  P5PL                                HWS05880
03DE 0  D020             837          STO       ME2                                 HWS05890
03DF 0  D246             838          STO    2  VT197
03E0 0  C29A             839          LD     2  VT102                               HWS05900
03E1 01 9400040B         840          S      L  P3PL                                HWS05930
03E3 0  D01C             841          STO       ME3                                 HWS05940
03E4 0  D247             842          STO    2  VT198
03E5 01 C400028F         843          LD     L  ENK                                 HWS05950
03E7 0  D019             844          STO       ME4                                 HWS05960
                         845   *                                                    HWS05970
03E8 0  C294             846          LD     2  VT108
03E9 01 94000413         847          S      L  P5TNB
03EB 01 D4000402         848          STO    L  MT1
```

Table B-11. Honeywell Control Program (Continued)


```
03ED 0  C29A               LD    2 VT102
03EE 01 94000412           S     L P3TNB
03F0 01 D4000403           STO   L MT2
03F2 0  D248               STO   2 VT199
03F3 01 C40001FA           LD    L T4WF
03F5 01 94000414           S     L TBBN
03F7 0  D00C               STO     MT3
03F8 0  D249               STO   2 VT200
03F9 01 C4000293           LD    L ETK
03FB 0  D009               STO     MT4
03FC 01 4C000417           B     L FREQE                              HWS06100
03FE 0  0000        ME1    DC      *-*                                HWS06110
03FF 0  0000        ME2    DC      *-*                                HWS06120
0400 0  0000        ME3    DC      *-*                                HWS06130
0401 0  0000        ME4    DC      *-*                                HWS06140
0402 0  0000        MT1    DC      *-*
0403 0  0000        MT2    DC      *-*
0404 0  0000        MT3    DC      *-*
0405 0  0000        MT4    DC      *-*
0406 0  0000        KEFN1  DC      *-*                                HWS06190
0407 0  0000        KEFN2  DC      *-*                                HWS06200
0408 0  0000        KEFN3  DC      *-*                                HWS06210
0409 0  0000        KEFN4  DC      *-*                                HWS06220
040A 0  0000        WEFN   DC      *-*                                HWS06230
040B 0  0000        P3PL   DC      *-*                                HWS06240
040C 0  0000        P5PL   DC      *-*                                HWS06250
040D 0  0000        KTFN1  DC      *-*
040E 0  0000        KTFN2  DC      *-*
040F 0  0000        KTFN3  DC      *-*
0410 0  0000        KTFN4  DC      *-*
0411 0  0000        WTFN   DC      *-*                                HWS06330
0412 0  0000        P3TNB  DC      *-*
0413 0  0000        P5TNB  DC      *-*
0414 0  0000        TBBN   DC      *-*                                HWS06370
0415 0  0000        VFMNN  DC      *-*
0416 0  0000        SUMEF  DC      *-*                                HWS06380
                    *                                                 HWS06390
                    * AT THIS POINT THE FUEL FLOW REQUEST IS          HWS06400
                    * COMPUTED FOR THE THREE CONTROLLERS              HWS06410
                    * %IE EQUILIBRIUM,PRESSURE,AND TEMPERATURE        HWS06420
                    * AND A SELECT LOW DETERMINS WHICH CONTROLLER     HWS06430
                    * WILL BE USED                                    HWS06440
0417                FREQE  EQU     *                                  HWS06450
0417 01 C4000406           LD    L KEFN1                              HWS06460
0419 0  A0E4               M       ME1                                HWS06470
041A 0  1087               SLT     7
041B 0  D24A               STO   2 VT201
041C 0  D0F9               STO     SUMEF                              HWS06490
041D 01 C4000407           LD    L KEFN2                              HWS06500
041F 0  A0DF               M       ME2                                HWS06510
0420 0  A818               D       =100
0421 0  1989               SRT     9
0422 0  80F3               A       SUMEF                              HWS06530
0423 0  D0F2               STO     SUMEF                              HWS06540
0424 01 C4000408           LD    L KEFN3                              HWS06550
0426 0  A0D9               M       ME3                                HWS06560
0427 0  A811               D       =100
```

Table B-11. Honeywell Control Program (Continued)


```
0428 0  1889                   SRT     9
0429 0  80EC                   A       SUMEF                      HWS06580
042A 0  D0EB                   STO     SUMEF                      HWS06590
042B 01 C4000409               LD   L  KEFN4                      HWS06600
042D 0  A0D3                   M       ME4                        HWS06610
042E 0  1084                   SLT     4
042F 0  D24D                   STO   2 VT204
0430 0  80E5                   A       SUMEF                      HWS06630
0431 0  D0E4                   STO     SUMEF                      HWS06650
0432 01 C400040A               LD   L  WEFN                       HWS06670
0434 0  1882                   SRT     2
0435 0  80E0                   A       SUMEF                      HWS06700
0436 0  D0DF                   STO     SUMEF                      HWS06720
0437 01 4C00043B               B    L  FREQP                      HWS06770
                               LORG                               HWS06780
0439 0  0064           +       DC      100
043A 0  0000           SUMPF   DC      *-*                        HWS06790
043B                   FREQP   EQU     *                          HWS06800
043B 0  C003                   LD      *32700                     HWS07160
043C 0  D0FD                   STO     SUMPF                      HWS07070
043D 01 4C000441               B    L  FREQT                      HWS07120
                               LORG                               HWS07130
043F 0  7FBC           +       DC      32700
0440 0  0000           SUMTF   DC      *-*                        HWS07140
0441                   FREQT   EQU     *                          HWS07150
0441 01 C400040D               LD   L  KTFN1
0443 01 A4000402               M    L  MT1
0445 0  A8F3                   D       =100
0446 0  1889                   SRT     9
0447 0  D0F8                   STO     SUMTF
0448 01 C400040E               LD   L  KTFN2
044A 01 A4000403               M    L  MT2
044C 0  A8EC                   D       =100
044D 0  1889                   SRT     9
044E 0  D24E                   STO   2 VT205
044F 0  80F0                   A       SUMTF
0450 0  D0EF                   STO     SUMTF
0451 01 C400040F               LD   L  KTFN3
0453 01 A4000404               M    L  MT3
0455 0  A813                   D       =10
0456 0  1889                   SRT     9
0457 0  D24F                   STO   2 VT206
0458 0  80E7                   A       SUMTF
0459 0  D0E6                   STO     SUMTF
045A 01 C4000410               LD   L  KTFN4
045C 01 A4000405               M    L  MT4
045E 0  1083                   SLT     3
045F 0  D250                   STO   2 VT207
0460 0  80DF                   A       SUMTF
0461 0  D0DE                   STO     SUMTF
0462 01 C4000411               LD   L  WTFN
0464 0  1882                   SRT     2
0465 0  80DA                   A       SUMTF
0466 0  D0D9                   STO     SUMTF
0467 01 4C00046E               B    L  MDSWT                      HWS07180
                               LORG                               HWS07190
0469 0  000A           +       DC      10
```

Table B-11. Honeywell Control Program (Continued)


```
046A 0  0CCC       963   ONE   DC       3276     HWS07200
046B 0  1998       964   TWO   DC       6552     HWS07210
046C 0  2664       965   THREE DC       9828     HWS07220
046D 0  0000       966   WFMOD DC       *-*      HWS07230
046E               967   MDSWT EQU      *        HWS07240
046E 01 C4000416   968         LD    L  SUMEF    HWS07250
0470 0  D2B9       969         STO   2  VT071    HWS07260
0471 01 C400043A   970         LD    L  SUMPF    HWS07270
0473 0  D2B8       971         STO   2  VT072    HWS07280
0474 01 C4000440   972         LD    L  SUMTF    HWS07290
0476 0  D2B7       973         STO   2  VT073    HWS07300
0477 0  B2B8       974         CMP   2  VT072    HWS07310
0478 0  C2B8       975         LD    2  VT072    HWS07320
0479 0  1000       976         NOP               HWS07330
047A 0  D0F2       977         STO      WFMOD    HWS07340
047B 0  B2B9       978         CMP   2  VT071    HWS07350
047C 0  C2B9       979         LD    2  VT071    HWS07360
047D 0  1000       980         NOP               HWS07370
047E 0  D235       981         STO   2  VT180    HWS07380
047F 01 4C28048A   982         BN       MINFL
0481 01 A4000505   983         M     L  =13      HWS06990
0483 0  1090       984         SLT      16       HWS07000
0484 0  D235       985         STO   2  VT180
0485 0  C235       986         LD    2  VT180
0486 01 94000415   987         S     L  WFMNN
0488 01 4C10048D   988         BNN      MINSS
048A 01 C4000415   989   MINFL LD    L  WFMNN
048C 0  D235       990         STO   2  VT180
048D               991   MINSS EQU      *
048D 0  C235       992         LD    2  VT180    HWS07390
048E 0  1890       993         SRT      16
048F 0  A875       994         D        =13
0490 0  92B9       995         S     2  VT071    HWS07400
0491 01 4C200497   996         BNZ      MIKE1    HWS07410
0493 0  C0D6       997         LD       ONE      HWS07420
0494 0  D2B6       998         STO   2  VT074    HWS07430
0495 01 4C0004AD   999         B     L  RQAIB    HWS07440
0497 0  C235      1000   MIKE1 LD    2  VT180    HWS07450
0498 0  1890      1001         SRT      16
0499 0  A868      1002         D        =13
049A 0  92B7      1003         S     2  VT073    HWS07460
049B 01 4C2004A1  1004         BNZ      MIKE2    HWS07470
049D 0  C0CD      1005         LD       TWO      HWS07480
049E 0  D2B6      1006         STO   2  VT074    HWS07490
049F 01 4C0004AD  1007         B     L  RQAIB    HWS07500
04A1 0  C0CA      1008   MIKE2 LD       THREE    HWS07510
04A2 0  D2B6      1009         STO   2  VT074    HWS07520
04A3 01 4C0004AD  1010         B     L  RQAIB    HWS07530
04A5 0  0031      1011   KLAGD DC       49
04A6 0  001F      1012   K1NUM DC       31
04A7 0  0009      1013   K2NUM DC       9
04A8 0  0000      1014   YNM1  DC       *-*
04A9 0  0000      1015   UNM1  DC       *-*
04AA    0000      1016   TEMF  BSS   E  0
04AA 0  0000      1017         DC       0
04AB 0  0000      1018         DC       0
04AC 0  0000      1019   SWLAG DC       *-*
```

Table B-11. Honeywell Control Program (Continued)


```
04AD              1020  RQAIB  EQU       *          HWS07540
04AD 01 C40004AC  1021         LD    L   SWLAG
04AF 01 4C2004BC  1022         BNZ       FILT
04B1 01 C4000506  1023         LD    L   =123
04B3 01 D40004AC  1024         STO   L   SWLAG
04B5 0  C235      1025         LD    2   VT180
04B6 01 D40004A8  1026         STO   L   YNM1
04B8 01 D40004A9  1027         STO   L   UNM1
04BA 01 4C0004D6  1028         B     L   DONOZ
04BC 01 C40004A9  1029  FILT   LD    L   UNM1
04BE 01 A40004A7  1030         M     L   K2NUM
04C0 01 DC0004AA  1031         STD   L   TEMF
04C2 0  C235      1032         LD    2   VT180
04C3 01 D40004A9  1033         STO   L   UNM1
04C5 01 A40004A7  1034         M     L   K2NUM
04C7 01 8C0004AA  1035         AD    L   TEMF
04C9 01 DC0004AA  1036         STD   L   TEMF
04CB 01 C40004A8  1037         LD    L   YNM1
04CD 01 A40004A6  1038         M     L   K1NUM
04CF 01 8C0004AA  1039         AD    L   TEMF
04D1 01 AC0004A5  1040         D     L   KLAGD
04D3 01 D40004A8  1041         STO   L   YNM1
04D5 0  D235      1042         STO   2   VT180
04D6              1043  DONOZ  EQU       *
04D6 0  C286      1044         LD    2   VT074
04D7 01 9400046A  1045         S     L   ONE
04D9 01 4C2004E0  1046         BNZ       GT10
04DB 0  C201      1047         LD    2   VT128
04DC 01 D4000507  1048         STO   L   NA8
04DE 01 4C0004E3  1049         B     L   CALA8
04E0 0  C21E      1050  GT10   LD    2   VT157
04E1 01 D4000507  1051         STO   L   NA8
04E3 01 C4000507  1052  CALA8  LD    L   NA8
04E5 01 940000F9  1053         S     L   =14025
04E7 01 4C1004ED  1054         BNN       GT11
04E9 0  C2DE      1055         LD    2   VT034
04EA 0  D2AF      1056         STO   2   VT081
04EB 01 4C000509  1057         B     L   CONT
04ED 01 940000FA  1058  GT11   S     L   =2475
04EF 01 4C2804F5  1059         BN        GT12
04F1 0  C2DD      1060         LD    2   VT035
04F2 0  D2AF      1061         STO   2   VT081
04F3 01 4C000509  1062         B     L   CONT
04F5 0  C2DE      1063  GT12   LD    2   VT034
04F6 0  92DD      1064         S     2   VT035
04F7 01 D4000508  1065         STO   L   ANOZN
04F9 01 C40000F5  1066         LD    L   =16500
04FB 01 94000507  1067         S     L   NA8
04FD 01 A4000508  1068         M     L   ANOZN
04FF 01 AC0000FA  1069         D     L   =2475
0501 0  82DD      1070         A     2   VT035
0502 0  D2AF      1071         STO   2   VT081
0503 01 4C000509  1072         B     L   CONT
                  1073         LORG
0505 0  000D      1074  +      DC        13
0506 0  007B      1075  +      DC        123
0507 0  0000      1076  NA8    DC        *-*
```

Table B-11. Honeywell Control Program (Continued)


```
0508 0  0000       1077   ANOZN  OC        *-*
0509               1078   CONT   EQU       *                      HWS07700
0509 00 65000000   1079   XR1    LDX   L1  *-*                    HWS07710
0508 01 4C800000   1080          BSC   I   HWECT                  HWS07720
FFB9               1081   VT071  EQU       -71                    HWS07730
FFB8               1082   VT072  EQU       -72                    HWS07740
FFB7               1083   VT073  EQU       -73                    HWS07750
FFB6               1084   VT074  EQU       -74                    HWS07760
FFAF               1085   VT081  EQU       -81                    HWS07770
FFAE               1086   VT082  EQU       -82                    HWS07780
FFAD               1087   VT083  EQU       -83                    HWS07790
001E               1088   VT157  EQU       +30                    HWS07800
0035               1089   VT180  EQU       +53                    HWS07810
0001               1090   VT128  EQU       +1                     HWS07820
FF9A               1091   VT102  EQU       -102                   HWS07830
FF94               1092   VT108  EQU       -108                   HWS07840
FF9F               1093   VT097  EQU       -97                    HWS07850
FFDC               1094   VT036  EQU       -36                    HWS07860
FFDB               1095   VT037  EQU       -37                    HWS07870
FFDA               1096   VT038  EQU       -38                    HWS07880
FFD9               1097   VT039  EQU       -39                    HWS07890
0023               1098   VT162  EQU       +35                    HWS07900
0024               1099   VT163  EQU       +36                    HWS07910
0025               1100   VT164  EQU       +37                    HWS07920
0026               1101   VT165  EQU       +38                    HWS07930
0027               1102   VT166  EQU       +39                    HWS07940
0028               1103   VT167  EQU       +40                    HWS07950
0029               1104   VT168  EQU       +41                    HWS07960
002A               1105   VT169  EQU       +42                    HWS07970
002B               1106   VT170  EQU       +43                    HWS07980
002C               1107   VT171  EQU       +44                    HWS07990
002D               1108   VT172  EQU       +45                    HWS08000
002E               1109   VT173  EQU       +46                    HWS08010
002F               1110   VT174  EQU       +47                    HWS08020
0030               1111   VT175  EQU       +48                    HWS08030
0031               1112   VT176  EQU       +49                    HWS08040
004F               1113   VT206  EQU       +79
0050               1114   VT207  EQU       +80
0045               1115   VT196  EQU       +69
0046               1116   VT197  EQU       +70
0047               1117   VT198  EQU       +71
0048               1118   VT199  EQU       +72
0049               1119   VT200  EQU       +73
004A               1120   VT201  EQU       +74
004B               1121   VT202  EQU       +75
004C               1122   VT203  EQU       +76
004D               1123   VT204  EQU       +77
004E               1124   VT205  EQU       +78
FFF4               1125   VT012  EQU       -12
FFF3               1126   VT013  EQU       -13
FFF2               1127   VT014  EQU       -14
FFF1               1128   VT015  EQU       -15
FFF0               1129   VT016  EQU       -16
FFEF               1130   VT017  EQU       -17
FFEE               1131   VT018  EQU       -18
FFED               1132   VT019  EQU       -19
FFEC               1133   VT020  EQU       -20
```

Table B-11. Honeywell Control Program (Concluded)


```
FFEB     1134   VT021 EQU    -21
FFEA     1135   VT022 EQU    -22
FFE9     1136   VT023 EQU    -23
FFD8     1137   VT040 EQU    -40
FFD7     1138   VT041 EQU    -41
FFD6     1139   VT042 EQU    -42
FFD5     1140   VT043 EQU    -43
FFD4     1141   VT044 EQU    -44
FFD3     1142   VT045 EQU    -45
FFD2     1143   VT046 EQU    -46
FFD1     1144   VT047 EQU    -47
FFD0     1145   VT048 EQU    -48
FFCF     1146   VT049 EQU    -49
FFCE     1147   VT050 EQU    -50
FFC3     1148   VT061 EQU    -61
FFC2     1149   VT062 EQU    -62
FFC1     1150   VT063 EQU    -63
FFC0     1151   VT064 EQU    -64
FFBF     1152   VT065 EQU    -65
FFBE     1153   VT066 EQU    -66
FFBD     1154   VT067 EQU    -67
FFBC     1155   VT068 EQU    -68
FFBB     1156   VT069 EQU    -69
FFDE     1157   VT034 EQU    -34
FFDD     1158   VT035 EQU    -35
FFB5     1159   VT075 EQU    -75
FFB4     1160   VT076 EQU    -76
FFB3     1161   VT077 EQU    -77
FFB2     1162   VT078 EQU    -78
FFAC     1163   VT084 EQU    -84
FFAB     1164   VT085 EQU    -85
FFAA     1165   VT086 EQU    -86
FFA9     1166   VT087 EQU    -87
FFA8     1167   VT088 EQU    -88
FFA7     1168   VT089 EQU    -89
FFB1     1169   VT079 EQU    -79
FFB0     1170   VT080 EQU    -80
FFA6     1171   VT090 EQU    -90
050E     1172         END

000 ERROR(S) AND 000 WARNING(S) IN ABOVE ASSEMBLY.
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Table B-12. Honeywell Control Program Cross Reference

SYMBOL	VALUE	REL	DEFN	REFERENCES-											
AMOZN	0508	1	1077	1065M	1068R										
BUMP1	010C	1	218	245R	292R	339R									
CALAB	04E3	1	1052	1049R											
CUNT	0509	1	1078	1057R	1062R	1072R									
CX1	0362	1	733	687M	689R	712M	714R	748M	750R	765R	774R	783R			
CX2	0363	1	734	690M	715M	751M	768R	777R	786R						
C1	0089	1	138	134M	153M	162M	164R	174M	176R	185M	187R	228R	275R	322R	
C11	010F	1	221	229M	236R										
C12	0145	1	268	276M	283R										
C13	017B	1	315	323M	330R										
C2	008A	1	139	136M	155M	165M	177M	188M	230R	277R	324R				
C21	0110	1	222	231M	239R										
C22	0146	1	269	278M	286R										
C23	017C	1	316	325M	333R										
DONOZ	04D6	1	1043	1028R											
DT	028E	1	565	455R	577R	591R									
ENDK	0288	1	559	510M	521R	575R	652R								
ENDK1	0289	1	560	527M	576R	653M									
ENK	028F	1	566	476M	479R	528M	531R	580R	581M	586M	602R	607M	610R	615M	799R
				843R											
ENKL	0290	1	567	480M	532M	604R	606R	611R	614R						
EPDK	028A	1	561	513M	523R	654R									
EPDK1	028B	1	562	524M	655M										
EPK	0291	1	568	483M	486R	535M	538R	617R	622M	625R	630M				
EPKL	0292	1	569	487M	539M	619R	621R	626R	629R						
ETDK	028C	1	563	516M	525R	589R	656R								
ETDK1	028D	1	564	526M	590R	657M									
ETK	0293	1	570	489M	492R	[illegible]	544R	594R	595M	600M	632R	637M	640R	645M	815R
				857R											
ETKL	0294	1	571	493M	545M	634R	636R	641R	644R						
FILT	04BC	1	1029	1022R											
FREQE	0417	1	891	859R											
FREQP	043B	1	925	919R											
FREQT	0441	1	930	926R											
FT4W	0181	1	363												
FT4WC	01E3	1	400	383R											
FUELM	01B1	1	362	249R	296R	343R									
GT10	04E0	1	1050	1046R											
GT11	04ED	1	1058	1054R											
GT12	04F5	1	1063	1059M											
HWECT	0000	1	2	1R	1080R										
IASCW	FEBF	C-COMMON													
IBTO	FF00	C-COMMON													
IDUMY	FFFF	C-COMMON													
INTEG	0295	1	573	518R	548R										
IN1F	0114	1	227	137R	168R										
IN2F	014A	1	274	180R											
IN3F	0180	1	321	156R	191R										
ISW	01FD	1	429	110M	431R	433M									
IVT00	FF80	C-COMMON													
JDUMY	FF7F	C-COMMON													
KEFN1	0406	1	868	243M	290M	337M	803R	892R							
KEFN2	0407	1	869	805R	897R										
KEFN3	0408	1	870	903R											
KEFN4	0409	1	871	809R	909R										
KEF11	00FC	1	201	17M	235R										
KEF12	00FD	1	202												
KEF13	00FE	1	203												
KEF14	00FF	1	204	24M											

Table B-12. Honeywell Control Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-		
KEF21	0135	1	251	27M	238R	282R
KEF22	0136	1	252			
KEF23	0137	1	253			
KEF24	0138	1	254	34M		
KEF31	016B	1	298	37M	285R	329R
KEF32	016C	1	299			
KEF33	016D	1	300			
KEF34	016E	1	301	44M		
KEF41	01A1	1	345	47M	332R	
KEF42	01A2	1	346			
KEF43	01A3	1	347			
KEF44	01A4	1	348	54M		
KLAGD	04A5	1	1011	1040R		
KTFN1	040D	1	875	817R	931R	
KTFN2	040E	1	876	819R	936R	
KTFN3	040F	1	877	821R	943R	
KTFN4	0410	1	878	823R	950R	
KTF11	0103	1	209	57M		
KTF12	0104	1	210	60M		
KTF13	0105	1	211	63M		
KTF14	0106	1	212	66M		
KTF21	013C	1	259	71M		
KTF22	013D	1	260	73M		
KTF23	013E	1	261	76M		
KTF24	013F	1	262	79M		
KTF31	0172	1	306	84M		
KTF32	0173	1	307	86M		
KTF33	0174	1	308	89M		
KTF34	0175	1	309	92M		
KTF41	01A8	1	353	96M		
KTF42	01A9	1	35	98M		
KTF43	01AA	1	355	101M		
KTF44	01AB	1	356	104M		
K1NUM	04A6	1	1012	1038R		
K1THD	01FB	1	427	374M	391M	447R
K2NUM	04A7	1	1013	1030R	1034R	
LUP1	011D	1	234	248M		
LUP2	0153	1	281	295M		
LUP3	0189	1	328	342M		
MDSWT	046E	1	967	960R		
MDW1	0309	1	672	664M		
MDW2	031B	1	682	674R		
MDW3	033E	1	707	684M		
MDW4	036C	1	744	709M		
MDW5	0388	1	764	703R	728R	
MDW6	03A7	1	794	671R	681R	791R
MDW9	024B	1	494	473R		
MEAST	FEFF		C-COMMON			
MEPT	03D7	1	830			
ME1	03FE	1	860	833M	893R	
ME2	03FF	1	861	837M	898R	
ME3	0400	1	862	841M	904R	
ME4	0401	1	863	844M	910R	
MICK	00AD	1	127	13R		
MIKE1	0497	1	1000	996R		
MIKE2	04A1	1	1008	1004R		
MINFL	048A	1	989	982M		
MINSS	048D	1	991	988R		
MT1	0402	1	864	848M	932R	

Table B-12. Honeywell Control Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-									
MT2	0403	1	865	851M	937R								
MT3	0404	1	866	855M	944R								
MT4	0405	1	867	858M	951R								
MW1	02BE	1	609	603M									
MW2	02C5	1	616	605R	608R	612R							
MW3	02CF	1	624	618M									
MW4	02D6	1	631	620R	623R	627R							
MW5	02E0	1	639	633M									
MW6	02E8	1	651	635R	638R	642R	646R						
NA8	0507	1	1076	1048M	1051M	1052R	1067R						
NEXT	01CD	1	384	366R									
NGET	010E	1	220	247R	294R	341R							
NIN	00BB	1	140	132M	151M	167M	179M	190M					
NM1	02A3	1	589	584R									
NM2	02B4	1	602	598R									
NPL1	035E	1	729	662R									
NPL2	035F	1	730	682R									
NPL3	0360	1	731	707R									
NPL4	0361	1	732	672R	744R								
ONE	046A	1	963	519R	583R	997R	1045R						
PLA	02F7	1	661										
P3E1	0101	1	206	665R	691R								
P3E2	013A	1	256	693R	716R								
P3E3	0170	1	303	718R	752R								
P3E4	01A6	1	350	675R	754R								
P3L	0364	1	735	692M	717M	753M	764R						
P3M	0365	1	736	694M	719M	755M	767R						
P3PL	040B	1	873	666M	676M	772M	797R	840R					
P3TNB	0412	1	880	511R	813R	850R							
P3T1	0108	1	214	21M									
P3T2	0141	1	264	31M									
P3T3	0177	1	311	41M									
P3T4	01AD	1	358	51M									
P5E1	0102	1	207	667R	695R								
P5E2	013B	1	257	697R	720R								
P5E3	0171	1	304	722R	756R								
P5E4	01A7	1	351	677R	758R								
P5L	0366	1	737	696M	721M	757M	773R						
P5M	0367	1	738	698M	723M	759M	776R						
P5PL	040C	1	874	668M	678M	781M	795R	836R					
P5TNB	0413	1	881	811R	847R								
P5T1	0109	1	215	120M									
P5T2	0142	1	265	122M									
P5T3	0178	1	312	124M									
P5T4	01AE	1	359	126M									
RQAIB	04AD	1	1020	999R	1007R	1010R							
SENL	0238	1	480	477R									
SEPL	0240	1	487	484R									
SETL	0249	1	493	490R									
SETX1	010D	1	219	232R	279R	326R							
STENL	0269	1	532	529R									
STEPL	0271	1	539	536R									
STETL	027A	1	545	542R									
STP1	01FE	1	430	400R									
STP2	020E	1	442	432R									
STP3	0219	1	452	441R									
SUMEF	0416	1	884	896M	901R	902M	907R	908M	913R	914M	917R	918M	968R
SUMPF	043A	1	922	925M	970R								
SUMTF	0440	1	923	935M	941R	942M	948R	949M	954R	955M	958R	959M	972R

Table B-12. Honeywell Control Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-							
SUMX	036A	1	741	766M	769R	775M	778R	784M	787R		
SUM1	0112	1	224	237M	240R						
SUM2	0148	1	271	284M	287R						
SUM3	017E	1	318	331M	334R						
SWLAG	04AC	1	1019	108M	1021R	1024M					
TAU2T	01FC	1	428	382M	399M	449R	466R				
TBBN	0414	1	802	514R	825R	854R					
TB1	010A	1	216	112M							
TB2	0143	1	265	114M							
TB3	0179	1	313	116M							
TB4	01AF	1	360	118M							
TEMF	04AA	1	1016	1031M	1035R	1036M	1039R				
TESTN	0007	1	10	6R							
THREE	046C	1	965	1008R							
TIME	0287	1	558	109M	517R	547M					
TIN1	00C0	1	157	149R							
TIN2	00DB	1	169	159M							
TIN3	00E9	1	181	171M							
TMAX	00C1	1	147	130R							
TMPF	01F2	1	414	369M	372R	377M	380R	386M	389R	394M	397R
TST1	0111	1	223	233M	234R	244R	246M				
TST2	0147	1	270	280M	281R	291R	293M				
TST3	017D	1	317	327M	328R	338R	340M				
TWO	046B	1	964	597R	1005R						
T4WF	01FA	1	426	469M	515R	853R					
UNM1	04A9	1	1015	1027M	1029R	1033M					
VT012	FFF4	0	1125	15R							
VT013	FFF3	0	1126	18R							
VT014	FFF2	0	1127	20R							
VT015	FFF1	0	1128	22R							
VT016	FFF0	0	1129	25R							
VT017	FFEF	0	1130	28R							
VT018	FFEE	0	1131	30R							
VT019	FFED	0	1132	32R							
VT020	FFEC	0	1133	35R							
VT021	FFEB	0	1134	38R							
VT022	FFEA	0	1135	40R							
VT023	FFE9	0	1136	42R							
VT034	FFDE	0	1157	1055R	1063R						
VT035	FFDD	0	1158	1060R	1064R	1070R					
VT036	FFDC	0	1094	475R	527R						
VT037	FFDB	0	1095	481R	533R						
VT038	FFDA	0	1096	488R	540R						
VT039	FFD9	0	1097	11R	14M	471R	474M				
VT040	FFD8	0	1137	45R							
VT041	FFD7	0	1138	48R							
VT042	FFD6	0	1139	50R							
VT043	FFD5	0	1140	52R							
VT044	FFD4	0	1141	55R							
VT045	FFD3	0	1142	58R							
VT046	FFD2	0	1143	61R							
VT047	FFD1	0	1144	64R							
VT048	FFD0	0	1145	67R							
VT049	FFCF	0	1146	69R							
VT050	FFCE	0	1147	72R							
VT061	FFC3	0	1148	74R							
VT062	FFC2	0	1149	77R							
VT063	FFC1	0	1150	80R							
VT064	FFC0	0	1151	82R							

Table B-12. Honeywell Control Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-								
VT065	FFBF	0	1152	85R								
VT066	FFBE	0	1153	87R								
VT067	FFBD	0	1154	90R								
VT068	FFBC	0	1155	93R								
VT069	FFBB	0	1156	95R								
VT071	FFB9	0	1081	969M	978R	979R	995R					
VT072	FFB8	0	1082	971M	974R	975R						
VT073	FFB7	0	1083	973M	1003R							
VT074	FFB6	0	1084	520M	582R	596R	998M	1006M	1009M	1044R		
VT075	FFB5	0	1159	97R								
VT076	FFB4	0	1160	99R								
VT077	FFB3	0	1161	102R								
VT078	FFB2	0	1162	105R								
VT079	FFB1	0	1169									
VT080	FFB0	0	1170	460M								
VT081	FFAF	0	1085	1056M	1061M	1071M						
VT082	FFAE	0	1086	111R								
VT083	FFAD	0	1087	113R								
VT084	FFAC	0	1163	115R								
VT085	FFAB	0	1164	117R								
VT086	FFAA	0	1165	119R								
VT087	FFA9	0	1166	121R								
VT088	FFA8	0	1167	123R								
VT089	FFA7	0	1168	125R								
VT090	FFA6	0	1171	462M								
VT097	FF9F	0	1093	438R	444R							
VT102	FF9A	0	1091	364R	370R	375R	387R	392R	512R	839R	849R	
VT108	FF94	0	1092	835R	846R							
VT128	0001	0	1090	508R	663R	673R	683R	708R	745R	832R	1047R	
VT157	001E	0	1088	128R	148R	158R	170R	182R	509R	831R	1050R	
VT162	0023	0	1098	796M								
VT163	0024	0	1099	798M								
VT164	0025	0	1100	800M								
VT165	0026	0	1101	802M								
VT166	0027	0	1102	804M								
VT167	0028	0	1103	806M								
VT168	0029	0	1104	808M								
VT169	002A	0	1105	810M								
VT170	002B	0	1106	812M								
VT171	002C	0	1107	814M								
VT172	002D	0	1108	816M								
VT173	002E	0	1109	818M								
VT174	002F	0	1110	820M								
VT175	0030	0	1111	822M								
VT176	0031	0	1112	824M								
VT180	0035	0	1089	981M	985M	986R	990M	992R	1000R	1025R	1032R	1042M
VT196	0045	0	1115	834M								
VT197	0046	0	1116	838M								
VT198	0047	0	1117	842M								
VT199	0048	0	1118	852M								
VT200	0049	0	1119	856M								
VT201	004A	0	1120	895M								
VT202	004B	0	1121	826M								
VT203	004C	0	1122	470M								
VT204	004D	0	1123	912M								
VT205	004E	0	1124	940M								
VT206	004F	0	1113	947M								
VT207	0050	0	1114	953M								
WEFL	0368	1	739	700M	725M	761M	782R					

Table B-12. Honeywell Control Program Cross Reference (Concluded)

SYMBOL	VALUE	REL	DEFN	REFERENCES-				
WEFM	0369	1	740	702M	727M	763M	785R	
WEFN	040A	1	872	670M	680M	790M	801R	915R
WEF1	0100	1	205	19M	669R	699R		
WEF2	0139	1	255	29M	701R	724R		
WEF3	016F	1	302	39M	726R	760R		
WEF4	01A5	1	349	49M	679R	762R		
WFMNN	0415	1	883	987R	989R			
WFMN1	010B	1	217					
WFMN2	0144	1	267					
WFMN3	017A	1	314					
WFMN4	01B0	1	361					
WFMOD	046D	1	966	977M				
WTFN	0411	1	879	807R	956R			
WTF1	0107	1	213	68M				
WTF2	0140	1	263	81M				
WTF3	0176	1	310	94M				
WTF4	01AC	1	357	106M				
XR1	0509	1	1079	3M				
XT4	01F4	1	417	440M	446R	458R	459M	467R
XT4D	01F6	1	420	436M	451M	452R	463R	
XT4D1	01F8	1	423	437M	453R	464M		
YNM1	04A8	1	1014	1026M	1037R	1041M		

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HWECT
DMP FUNCTION COMPLETED
*STORE              HWECT
HWECT
DMP FUNCTION COMPLETED
```

Table B-13. Bendix Bounds Program

```
// JOB          VDISK    17 JUL 74 15.768 HRS
// DMP    17 JUL 74 15.768 HRS
*DELETE                  GTECT
DMP FUNCTION COMPLETED
// ASM GTECT    17 JUL 74 15.769 HRS                                          HWE00010
*OVERFLOW SECTORS ,,,9                                                        HWE00020
*LIST                                                                         HWE00030
*XREF                                                                         HWE00040
*ONE WORD INTEGERS                                                            HWE00050
*COMMON IDUMY(127),IVT00,JDUMY(127),I370,MEAST(64),IASCW(2)                   HWE00060
0000      078C50E3      1           ENT        GTECT                                HWE00070
0000 0    0000          2    GTECT  DC         *-*                                  HWE00080
0001 01   6D000568      3           STX   L1   XR1+1                                HWE00090
0003 01   6E00056A      4           STX   L2   XR2+1                                HWE00100
0005 01   6F00056C      5           STX   L3   XR3+1                                HWE00110
                        6    *                                                      HWE00120
0007 03   67C0FEC0      7           LDX   L3   MEAST-63                             HWE00130
0009 03   6600FF80      8           LDX   L2   IVT00                                HWE00140
000B 00   65000000      9           LDX   L1   0                                    HWE00150
000D 0    C03F         10           LD         =0                                   HWE00160
                       11    *                                                      HWE00170
000E 01   4C000147     12           B     L    START                                HWE00180
0010                   13    RSTAL  EQU        *          RESET ALL DIGITAL ADJUST  HWE00190
0010 0    C03E         14           LD         ST001                                HWE00200
0011 0    D2FF         15           STO   2    VT001                                HWE00210
0012 0    C03D         16           LD         ST002                                HWE00220
0013 0    D2FE         17           STO   2    VT002                                HWE00230
0014 0    C03C         18           LD         ST003                                HWE00240
0015 0    D2FD         19           STO   2    VT003                                HWE00250
0016 0    C03B         20           LD         ST004                                HWE00260
0017 0    D2FC         21           STO   2    VT004                                HWE00270
0018 0    C03A         22           LD         ST005                                HWE00280
0019 0    D2FB         23           STO   2    VT005                                HWE00290
001A 0    C039         24           LD         ST006                                HWE00300
001B 0    D2FA         25           STO   2    VT006                                HWE00310
001C 0    C038         26           LD         ST007                                HWE00320
001D 0    D2F9         27           STO   2    VT007                                HWE00330
001E 0    C037         28           LD         ST008                                HWE00340
001F 0    D2F8         29           STO   2    VT008                                HWE00350
0020 0    C036         30           LD         ST009                                HWE00360
0021 0    D2F7         31           STO   2    VT009                                HWE00370
0022 0    C035         32           LD         ST010                                HWE00380
0023 0    D2F6         33           STO   2    VT010                                HWE00390
0024 0    C034         34           LD         ST011                                HWE00400
0025 0    D2F5         35           STO   2    VT011                                HWE00410
0026 0    C033         36           LD         ST012                                HWE00420
0027 0    D2F4         37           STO   2    VT012                                HWE00430
0028 0    C032         38           LD         ST013                                HWE00440
0029 0    D2F3         39           STO   2    VT013                                HWE00450
002A 0    C031         40           LD         ST014                                HWE00460
002B 0    D2F2         41           STO   2    VT014                                HWE00470
002C 0    C030         42           LD         ST015                                HWE00480
002D 0    D2F1         43           STO   2    VT015                                HWE00490
002E 0    C02F         44           LD         ST016                                HWE00500
002F 0    D2F0         45           STO   2    VT016                                HWE00510
0030 0    C02E         46           LD         ST017                                HWE00520
0031 0    D2EF         47           STO   2    VT017                                HWE00530
0032 0    C02D         48           LD         ST018                                HWE00540
0033 0    D2EE         49           STO   2    VT018                                HWE00550
0034 0    C02C         50           LD         ST019                                HWE00560
```

Table B-13. Bendix Bounds Program (Continued)


```
0035 0  D2ED    51          STO   2 VT019                                HWE00570
0036 0  C02B    52          LD      ST020                                HWE00580
0037 0  D2EC    53          STO   2 VT020                                HWE00590
0038 0  C02A    54          LD      ST021                                HWE00600
0039 0  D2EB    55          STO   2 VT021                                HWE00610
003A 0  C029    56          LD      ST022                                HWE00620
003B 0  D2EA    57          STO   2 VT022                                HWE00630
003C 0  C028    58          LD      ST023                                HWE00640
003D 0  D2E9    59          STO   2 VT023                                HWE00650
003E 0  C027    60          LD      ST024                                HWE00660
003F 0  D2E8    61          STO   2 VT024                                HWE00670
0040 0  C026    62          LD      ST025                                HWE00680
0041 0  D2E7    63          STO   2 VT025                                HWE00690
0042 0  C025    64          LD      ST026                                HWE00700
0043 0  D2E6    65          STO   2 VT026                                HWE00710
0044 0  C024    66          LD      ST027                                HWE00720
0045 0  D2E5    67          STO   2 VT027                                HWE00730
0046 0  C023    68          LD      ST028                                HWE00740
0047 0  D2E4    69          STO   2 VT028                                HWE00750
0048 0  C022    70          LD      ST029                                HWE00760
0049 0  D2E3    71          STO   2 VT029                                HWE00770
004A 0  C021    72          LD      ST030                                HWE00780
004B 0  D2E2    73          STO   2 VT030                                HWE00790
004C 0  705C    74          B       STTVT                                HWE00800
                75          LORG                                         HWE00810
004D 0  0000    76    +     DC      0
                77    *                      SPEED CONTROL FIG10-3&4     HWE00820
004E 0  0000    78    ST000 DC      0                                    HWE00830
004F 0  0000    79    ST001 DC      0        IDLE SPEED TRIM             HWE00840
0050 0  0000    80    ST002 DC      0        MAX  SPEED TRIM             HWE00850
0051 0  4E20    81    ST003 DC      20000                                HWE00860
0052 0  0000    82    ST004 DC      0            BRANCH COMMAND  64+     HWE00870
0053 0  1000    83    ST005 DC      4096         N INTEGRATION INC       HWE00880
0054 0  1388    84    ST006 DC      5000         N INT PRESS GAIN        HWE00890
0055 0  F000    85    ST007 DC      -4096        N INT DECREASE          HWE00900
0056 0  EC78    86    ST008 DC      -5000        N INT DEC PRESS GAIN    HWE00910
                87    *                                                  HWE00920
                88    *             FIG10-5  PROP.TEMPERATURE CONTROL    HWE00930
0057 0  0000    89    ST009 DC      0         SPEED CONTROL SELECTION    HWE00940
0058 0  2AF8    90    ST010 DC      11000                                HWE00950
0059 0  0000    91    ST011 DC      0        ZERO FLOW ADJUST            HWE00960
                92    *           HONEYWELL ST VALUES
                93    *
005A 0  F290    94    ST012 DC      -3440    N    GAIN  (50,E)
005B 0  0207    95    ST013 DC      519      WF         (50 ,E)
005C 0  0992    96    ST014 DC      2450     PT3 BOND (50 ,P)
005D 0  01B0    97    ST015 DC      432      EN   GAIN (50 ,E)
005E 0  F820    98    ST016 DC      -2016    N    GAIN (70 ,E)
005F 0  02B5    99    ST017 DC      693      WF        (70 ,E)
0060 0  0FA0   100    ST018 DC      4000     PT3 BOND (70 ,P)
0061 0  0190   101    ST019 DC      400      EN   GAIN (70 ,E)
0062 0  F860   102    ST020 DC      -1952    N    GAIN (85 ,E)
0063 0  03A6   103    ST021 DC      934      WF        (85 ,E)
0064 0  109C   104    ST022 DC      6300     PT3 BOND (85 ,P)
0065 0  0380   105    ST023 DC      896      EN   GAIN (85 ,E)
               106    *
               107    *            END HONEYWELL ST VALUES
```

Table B-13. Bendix Bounds Program (Continued)


```
                       108   *
0066 0  1770           109   ST024 DC    6000      ZERO N RATIOS INTERCEPT    HWE01140
0067 0  A240           110   ST025 DC    -24000    BACK SLOPE SPEED BREAK PT  HWE01150
0068 0  4000           111   ST026 DC    16384
                       112   *                                                HWE01170
                       113   *                  FIGURE10-8   RATIOS INTEGRATIONHWE01180
0069 0  7FF8           114   ST027 DC    32760
006A 0  0000           115   ST028 DC    0
006B 0  0000           116   ST029 DC    0         MINIMUM RATIOS SLOPE       HWE01210
006C 0  5014           117   ST030 DC    20500     MINIMUM RATIOS LEVEL       HWE01220
006D 0  0000           118   ST031 DC    0                                    HWE01230
006E 0  7FF8           119   ST032 DC    32760     VALVE MAXIMUM POSITION     HWE01240
006F 0  0000           120   ST033 DC    0         VALVE MINIMUM POSITION     HWE01250
0070 0  25A8           121   ST034 DC    9640
0071 0  0A5A           122   ST035 DC    2650
                       123   *
                       124   *        HONEYWELL ST VALUES
                       125   *
0072 0  0640           126   ST036 DC    1600
0073 0  0640           127   ST037 DC    1600
0074 0  567D           128   ST038 DC    22141
0075 0  0010           129   ST039 DC    16
0076 0  F0A0           130   ST040 DC    -3936     N    GAIN (100,E)
0077 0  0670           131   ST041 DC    1648      WF        (100,E)
0078 0  1FA4           132   ST042 DC    8100      PT3 BOND (100,P)
0079 0  0930           133   ST043 DC    2352      EN  GAIN (100,E)
007A 0  22D0           134   ST044 DC    8912      PT5 GAIN (50  T)
007B 0  FB66           135   ST045 DC    -1178     PT3 GAIN (50  T)
007C 0  F970           136   ST046 DC    -1680     T4W GAIN (50  T)
007D 0  0340           137   ST047 DC    832       ET GAIN (50  T)
007E 0  028B           138   ST048 DC    651       WTF (50  T)
007F 0  3A80           139   ST049 DC    14976     PT5 GAIN (70  T)
0080 0  6009           140   ST050 DC    24585     PT3 GAIN (70  T)
                       141   *
                       142   *        END HONEYWELL ST VALUES
                       143   *
                       144   *                                                HWE01460
                       145   *                  FIGURE10-12  IGV & BLEED CONTR  HWE01470
0081 0  0000           146   ST051 DC    0         LOW N TRIM OF IGV          HWE01480
0082 0  3E80           147   ST052 DC    16000     HIGH N TRIM OF IGV         HWE01490
0083 0  0000           148   ST053 DC    0         LOW N TRIM OF BLEEDS       HWE01500
0084 0  3E80           149   ST054 DC    16000     HIGH N TRIM OF BLEEDS      HWE01510
                       150   *                                                HWE01520
                       151   *                  FIGURE10-14 NOZZLE CONTROL    HWE01530
0085 0  105E           152   ST055 DC    4190      NOZZLE FLAT                BEN01530
0086 0  40D8           153   ST056 DC    16600     T5 REQUEST                 HWE01550
0087 0  4000           154   ST057 DC    16384     T5 CONTROL GAIN            HWE01560
0088 0  0000           155   ST058 DC    0                                    HWE01570
0089 0  0000           156   ST059 DC    0                                    HWE01580
008A 0  0000           157   ST060 DC    0                                    HWE01590
008B 0  F7CE           158   ST061 DC    -2098     T4W GAIN (70  T)
008C 0  0410           159   ST062 DC    1040      ET GAIN (70  T)
008D 0  03E8           160   ST063 DC    1000      WTF (70  T)
008E 0  EA90           161   ST064 DC    -5488     PT5 GAIN (85  T)
008F 0  108B           162   ST065 DC    4235      PT3 GAIN (85  T)
0090 0  FA95           163   ST066 DC    -1387     T4W GAIN (85  T)
0091 0  04A0           164   ST067 DC    1184      ET GAIN (85  T
```

Table B-13. Bendix Bounds Program (Continued)


```
0092 0  0898       165   ST068 DC        2200       WTF (85  T)
0093 0  17EF       166   ST069 DC        6127       PT5 GAIN (100 T)
0094 0  0000       167   ST070 DC        0
0095 0  0000       168   ST071 DC        0
0096 0  0000       169   ST072 DC        0
0097 0  0000       170   ST073 DC        0
0098 0  0000       171   ST074 DC        0
0099 0  DF6E       172   ST075 DC        -8338      PT3 GAIN (100 T)
009A 0  FFC0       173   ST076 DC        -64        T4W GAIN (100 T)
009B 0  06C0       174   ST077 DC        1728       ET GAIN (100 T)
009C 0  0BB8       175   ST078 DC        3000       WTF (100 T)
009D 0  0000       176   ST079 DC        0
009E 0  0000       177   ST080 DC        0
009F 0  0000       178   ST081 DC        0
00A0 0  299A       179   ST082 DC        10650
00A1 0  2666       180   ST083 DC        9830
00A2 0  30AC       181   ST084 DC        12460
00A3 0  2EE0       182   ST085 DC        12000
00A4 0  05DC       183   ST086 DC        1500
00A5 0  0690       184   ST087 DC        1680
00A6 0  0898       185   ST088 DC        2200
00A7 0  0B54       186   ST089 DC        2900
00A8 0  0000       187   ST090 DC        0
00A9               188   STTVT EQU       *                               HWE01600
00A9 0  C0C3       189         LD        ST031                           HWE01610
00AA 0  D2E1       190         STO     2 VT031                           HWE01620
00AB 0  C0C2       191         LD        ST032                           HWE01630
00AC 0  D2E0       192         STO     2 VT032                           HWE01640
00AD 0  C0C1       193         LD        ST033                           HWE01650
00AE 0  D2DF       194         STO     2 VT033                           HWE01660
00AF 0  C0C0       195         LD        ST034                           HWE01670
00B0 0  D2DE       196         STO     2 VT034                           HWE01680
00B1 0  C0BF       197         LD        ST035                           HWE01690
00B2 0  D2DD       198         STO     2 VT035                           HWE01700
00B3 0  C0BE       199         LD        ST036                           HWE01710
00B4 0  D2DC       200         STO     2 VT036                           HWE01720
00B5 0  C0BD       201         LD        ST037                           HWE01730
00B6 0  D2DB       202         STO     2 VT037                           HWE01740
00B7 0  C0BC       203         LD        ST038                           HWE01750
00B8 0  D2DA       204         STO     2 VT038                           HWE01760
00B9 0  C0BB       205         LD        ST039                           HWE01770
00BA 0  D2D9       206         STO     2 VT039                           HWE01780
00BB 0  C0BA       207         LD        ST040                           HWE01790
00BC 0  D2D8       208         STO     2 VT040                           HWE01800
00BD 0  C0B9       209         LD        ST041                           HWE01810
00BE 0  D2D7       210         STO     2 VT041                           HWE01820
00BF 0  C0B8       211         LD        ST042                           HWE01830
00C0 0  D2D6       212         STO     2 VT042                           HWE01840
00C1 0  C0B7       213         LD        ST043                           HWE01850
00C2 0  D2D5       214         STO     2 VT043                           HWE01860
00C3 0  C0B6       215         LD        ST044                           HWE01870
00C4 0  D2D4       216         STO     2 VT044                           HWE01880
00C5 0  C0B5       217         LD        ST045                           HWE01890
00C6 0  D2D3       218         STO     2 VT045                           HWE01900
00C7 0  C0B4       219         LD        ST046                           HWE01910
00C8 0  D2D2       220         STO     2 VT046                           HWE01920
00C9 0  C0B3       221         LD        ST047                           HWE01930
```

Table B-13. Bendix Bounds Program (Continued)


```
00CA 0  D2D1        222    STO  2 VT047    HWE01940
00CB 0  C0B2        223    LD     ST048    HWE01950
00CC 0  D2D0        224    STO  2 VT048    HWE01960
00CD 0  C0B1        225    LD     ST049    HWE01970
00CE 0  D2CF        226    STO  2 VT049    HWE01980
00CF 0  C0B0        227    LD     ST050    HWE01990
00D0 0  D2CE        228    STO  2 VT050    HWE02000
00D1 0  C0AF        229    LD     ST051    HWE02010
00D2 0  D2CD        230    STO  2 VT051    HWE02020
00D3 0  C0AE        231    LD     ST052    HWE02030
00D4 0  D2CC        232    STO  2 VT052    HWE02040
00D5 0  C0AD        233    LD     ST053    HWE02050
00D6 0  D2CB        234    STO  2 VT053    HWE02060
00D7 0  C0AC        235    LD     ST054    HWE02070
00D8 0  D2CA        236    STO  2 VT054    HWE02080
00D9 0  C0AB        237    LD     ST055    HWE02090
00DA 0  D2C9        238    STO  2 VT055    HWE02100
00DB 0  C0AA        239    LD     ST056    HWE02110
00DC 0  D2C8        240    STO  2 VT056    HWE02120
00DD 0  C0A9        241    LD     ST057    HWE02130
00DE 0  D2C7        242    STO  2 VT057    HWE02140
00DF 0  C0A8        243    LD     ST058    HWE02150
00E0 0  D2C6        244    STO  2 VT058    HWE02160
00E1 0  C0A7        245    LD     ST059    HWE02170
00E2 0  D2C5        246    STO  2 VT059    HWE02180
00E3 0  C0A6        247    LD     ST060    HWE02190
00E4 0  D2C4        248    STO  2 VT060    HWE02200
00E5 0  C0A5        249    LD     ST061
00E6 0  D2C3        250    STO  2 VT061
00E7 0  C0A4        251    LD     ST062
00E8 0  D2C2        252    STO  2 VT062
00E9 0  C0A3        253    LD     ST063
00EA 0  D2C1        254    STO  2 VT063
00EB 0  C0A2        255    LD     ST064
00EC 0  D2C0        256    STO  2 VT064
00ED 0  C0A1        257    LD     ST065
00EE 0  D2BF        258    STO  2 VT065
00EF 0  C0A0        259    LD     ST066
00F0 0  D2BE        260    STO  2 VT066
00F1 0  C09F        261    LD     ST067
00F2 0  D2BD        262    STO  2 VT067
00F3 0  C09E        263    LD     ST068
00F4 0  D2BC        264    STO  2 VT068
00F5 0  C09D        265    LD     ST069
00F6 0  D2BB        266    STO  2 VT069
00F7 0  C09C        267    LD     ST070
00F8 0  D2BA        268    STO  2 VT070
00F9 01 C4000095    269    LD   L ST071
00FB 0  D2B9        270    STO  2 VT071
00FC 01 C4000096    271    LD   L ST072
00FE 0  D2B8        272    STO  2 VT072
00FF 01 C4000097    273    LD   L ST073
0101 0  D2B7        274    STO  2 VT073
0102 01 C4000098    275    LD   L ST074
0104 0  D2B6        276    STO  2 VT074
0105 01 C4000099    277    LD   L ST075
0107 0  D2B5        278    STO  2 VT075
```

Table B-13. Bendix Bounds Program (Continued)


```
0108 01 C400009A    279            LD    L  ST076
010A 0   D2B4       280            STO   2  VT076
010B 01 C400009B    281            LD    L  ST077
010D 0   D2B3       282            STO   2  VT077
010E 01 C400009C    283            LD    L  ST078
0110 0   D2B2       284            STO   2  VT078
0111 01 C400009D    285            LD    L  STC79
0113 0   D2B1       286            STO   2  VT079
0114 01 C400009E    287            LD    L  ST080
0116 0   D2B0       288            STO   2  VT080
0117 01 C400009F    289            LD    L  ST081
0119 0   D2AF       290            STO   2  VT081
011A 01 C40000A0    291            LD    L  ST082
011C 0   D2AE       292            STO   2  VT082
011D 01 C40000A1    293            LD    L  ST083
011F 0   D2AD       294            STO   2  VT083
0120 01 C40000A2    295            LD    L  ST084
0122 0   D2AC       296            STO   2  VT084
0123 01 C40000A3    297            LD    L  ST085
0125 0   D2AB       298            STO   2  VT085
0126 01 C40000A4    299            LD    L  ST086
0128 0   D2AA       300            STO   2  VT086
0129 01 C40000A5    301            LD    L  ST087
012B 0   D2A9       302            STO   2  VT087
012C 01 C40000A6    303            LD    L  ST088
012E 0   D2A8       304            STO   2  VT088
012F 01 C40000A7    305            LD    L  ST089
0131 0   D2A7       306            STO   2  VT089
0132 01 C40000A8    307            LD    L  ST090
0134 0   D2A6       308            STO   2  VT090
0135 0   7054       309            B        DAC4L      BRANCH TO DAC4 OUTPUT LOOP HWE02210
                    310      *                                                 HWE02220
0136     0000       311      CEON  BSS   E  0                                  HWE02230
0136 0   0000       312            DC       0                                  HWE02240
0137 0   E401       313            DC       /E401                              HWE02250
                    314      *                    DIGITAL ADJUSTMENT           HWE02260
0138     0000       315      DIV64 BSS   E  0                                  HWE02270
0138 0   0000       316            DC       0                                  HWE02280
0139 0   5F40       317            DC       /5F40                              HWE02290
                    318      *                    SAFETY RESET DIGITAL WORD    HWE02300
013A     0000       319      DIV40 BSS   E  0                                  HWE02310
013A 0   0000       320            DC       0                                  HWE02320
013B 0   DF40       321            DC       /DF40                              HWE02330
                    322      *                                                 HWE02340
013C     0000       323      DU7E  BSS   E  0                                  HWE02350
013C 1   013E       324            DC       VALUE                              HWE02360
013D 0   617E       325            DC       /617E                              HWE02370
                    326      *                                                 HWE02380
013E 0   0000       327      VALUE DC       *-*                                HWE02390
013F 0   0000       328      NUM   DC       *-*                                HWE02400
0140 0   0000       329      TMNR  DC       *-*                                HWE02410
0141 0   0032       330      TRIMS DC       50                                 HWE02420
0142 0   0000       331      TEMP3 DC       *-*                                HWE02430
0143 0   0000       332      TEMP4 DC       *-*                                HWE02440
0144 0   0000       333      TEMP5 DC       *-*                                HWE02450
0145 0   0000       334      DKOUT DC       *-*                                HWE02460
0146 0   0000       335      DK20T DC       *-*                                HWE02470
```

Table B-13. Bendix Bounds Program (Continued)


```
                  *                 OBTAIN INPUT DATA                 HWE02480
0147              START EQU    *                                      HWE02490
0147 0  08EE            XIO    CEON                                   HWE02500
                  *                 DIGITAL ADJUSTMENTS               HWE02510
0148 0  08EF            XIO    DIV64                                  HWE02520
0149 01 E40001E4        AND  L =/7F80                                 HWE02540
014B 0  D2A2            STO  2 VT094      DIGITAL ADJUSTMENT          HWE02530
014C 0  1807            SRA    7                                      HWE02550
014D 0  D0F1            STO    NUM                                    HWE02560
014E 01 940001E5        S    L =127                                   HWE02570
0150 0  D0EF            STO    TMNR                                   HWE02580
0151 01 4C300157        BP     PLUS                                   HWE02590
0153 01 C400004D        LD   L =0                                     HWE02600
0155 0  90E9            S      NUM                                    HWE02610
0156 0  D0E9            STO    TMNR                                   HWE02620
0157 01 65800140  PLUS  LDX I1 TMNR                                   HWE02630
0159 03 C500FF80        LD  L1 IVT00                                  HWE02640
015B 0  D0E2            STO    VALUE                                  HWE02650
015C 0  D0E6            STO    TEMP4                                  HWE02660
015D 01 4C300' 5        BP     RDOUT                                  HWE02670
015F 01 C400  D         LD   L =0                                     HWE02680
0161 0  90DC            S      VALUE                                  HWE02690
0162 01 EC0001E6        OR   L =/8000                                 HWE02700
0164 0  D0D9            STO    VALUE                                  HWE02710
0165              RDOUT EQU    *                                      HWE02720
0165 0  08D6            XIO    DO7E                                   HWE02730
                  *                 VTXXX VALUE OUTPUT                HWE02740
                  *                 RESET AND SAFETY                  HWE02750
0166 0  08D3            XIO    DIV40                                  HWE02760
0167 0  E07F            AND    =/7FFF                                 HWE02770
0168 0  D0D9            STO    TEMP3                                  HWE02780
0169 0  D29B            STO  2 VT101                                  HWE02790
016A 0  E07D            AND    =/4000                                 HWE02800
016B 01 4C300010        BP     RSTAL      RESET ALL ADJUSTMENTS       HWE02810
                  *                 SINGLE ADJUSTMENT RESET ROUTINE   HWE02820
016D 0  C29D            LD   2 VT099                                  HWE02830
016E 0  90D0            S      NUM                                    HWE02840
016F 01 4C1801"         BZ     RSTSA                                  HWE02850
0171 0  C0CD            LD     NUM                                    HWE02860
0172 0  D29D            STO  2 VT099                                  HWE02870
0173 0  C0CF            LD     TEMP4                                  HWE02880
0174 0  D29C            STO  2 VT100                                  HWE02890
0175 0  C29B      RSTSA LD   2 VT101                                  HWE02900
0176 0  E072            AND    =/2000                                 HWE02910
0177 01 4C18018A        BZ     DAC4L                                  HWE02920
0179 0  C0C5            LD     NUM                                    HWE02930
017A 0  906F            S      =90        NUMBER OF ADJUSTMENTS       HWE02940
017B 01 4C30018A        BP     DAC4L                                  HWE02950
                  *RESET ONLY ONE TRIM                                HWE02960
017D 0  C06D            LD     =C                                     HWE02970
017E 0  90C0            S      NUM                                    HWE02980
017F 0  D0C4            STO    TEMP5                                  HWE02990
0180 01 6500004E        LDX L1 ST000                                  HWE03000
0182 01 7580013F        MDX I1 NUM                                    HWE03010
0184 0  C100            LD   1 0                                      HWE03020
0185 03 6500FF80        LDX L1 IVT00                                  HWE03030
0187 01 75800144        MDX I1 TEMP5                                  HWE03040
```

Table B-13. Bendix Bounds Program (Continued)


```
0189 0  D100      393            STO  1 0                                  HWE03050
                  394   * END RESET ONLY ONE TRIM                          HWE03060
                  395   *                    DAC4 OUTPUT                   HWE03070
018A              396   DAC4L EQU      *                                   HWE03080
018A 0  C29B      397          LD   2 VT101                                HWE03090
018B 0  E060      398          AND    =/1000                               HWE03100
018C 01 4C180190  399          BZ     DAC40                                HWE03110
018E 0  C0B1      400          LD     TMNR                                 HWE03120
018F 0  D216      401          STO  2 VT149                                HWE03130
                  402   *                    DAC4 OUTPUT ROUTINE           HWE03140
0190              403   DAC40 EQU      *                                   HWE03150
0190 0  C216      404          LD   2 VT149                                HWE03160
0191 0  D0B3      405          STO    DKOUT                                HWE03170
0192 01 65800145  406          LDX  I1 DKOUT                               HWE03180
0194 03 C500FF80  407          LD   L1 IVT00                               HWE03190
0196 0  1881      408          SRT    1                                    HWE03200
0197 01 D4000589  409          STO  L ALOG4                                HWE03210
0199 0  D250      410          STO  2 VT220                                HWE03220
                  411   *                                                  HWE03230
                  412   *                      OUTPUT VTXXX TO DAC 2       HWE03240
019A 0  C29B      413          LD   2 VT101                                HWE03250
019B 0  E051      414          AND    =/0800                               HWE03260
019C 01 4C1801A0  415          BZ     DAC20                                HWE03270
019E 0  C0A1      416          LD     TMNR                                 HWE03280
019F 0  D261      417          STO  2 VT224                                HWE03290
                  418   *                                                  HWE03300
01A0              419   DAC20 EQU      *                                   HWE03310
01A0 0  C261      420          LD   2 VT224                                HWE03320
01A1 0  D0A4      421          STO    DK20T                                HWE03330
01A2 01 65800146  422          LDX  I1 DK20T                               HWE03340
01A4 03 C500FF80  423          LD   L1 IVT00                               HWE03350
01A6 0  1881      424          SRT    1                                    HWE03360
01A7 01 D4000587  425          STO  L BLEED                                HWE03370
01A9 0  D262      426          STO  2 VT225                                HWE03380
                  427   *                                                  HWE03390
                  428   *                    VALVE POSITION SIMULATION     HWE03400
01AA 0  C29B      429          LD   2 VT101                                HWE03410
01AB 0  E042      430          AND    =/0400                               HWE03420
01AC 01 4C3001B8  431          BP     VLVEG  VALVE POSITION ENGINE         HWE03430
01AE 0  C29B      432          LD   2 VT101                                HWE03440
01AF 0  E03F      433          AND    =/00FF                               HWE03450
01B0 0  903F      434          S      =/00AA                               HWE03460
01B1 01 4C1801C6  435          BZ     SAFND  END OF SAFETY ROUTINE         HWE03470
01B3 0  C03D      436          LD     =-5000                               HWE03480
01B4 01 D4000585  437          STO  L FUEL                                 HWE03490
01B6 01 4C000551  438          B    L DONE                                 HWE03500
                  439   *                    VALVE POSITION ENGINE RUN     HWE03510
01B8              440   VLVEG EQU      *                                   HWE03520
01B8 0  C21E      441          LD   2 VT157                                HWE03530
01B9 0  9038      442          S      =7000                                HWE03540
01BA 01 4C3001C6  443          BP     SAFND                                HWE03550
01BC 0  C29B      444          LD   2 VT101                                HWE03560
01BD 0  E031      445          AND    =/00FF                               HWE03570
01BE 0  9034      446          S      =/0055                               HWE03580
01BF 01 4C1801C6  447          BZ     SAFND                                HWE03590
01C1 0  C02F      448          LD     =-5000                               HWE03600
01C2 01 D4000585  449          STO  L FUEL                                 HWE03610
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Table B-13. Bendix Bounds Program (Continued)

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```
01C4 01 4C000551   450            B    L  DONE                               HWE03620
01C6               451      SAFND EQU     *                                  HWE03630
                   452      *                   SPEED COMPUTATION            HWE03640
01C6 0  C02D       453            LD      =10                                HWE03650
01C7 01 D40001E2   454            STO  L  TESTN                              HWE03660
01C9 0  0816       455      GETN  XIO     RPM                                HWE03670
01CA 01 4C2801CF   456            BN      VALID                              HWE03680
01CC 01 74FF01E2   457            MDM     TESTN,-1                           HWE03690
01CE 0  70FA       458            B       GETN                               HWE03700
01CF               459      VALID EQU     *                                  HWE03710
01CF 0  EC17       460            AND     =/7FFF                             HWE03720
01D0 0  D012       461            STO     RAWN                               HWE03730
01D1 0  D2A3       462            STO  2  VT093        RAW SPEED             HWE03740
01D2 01 CC0001DE   463            LDD  L  KSUBN                              HWE03750
01D4 0  1885       464            SRT     5                                  HWE03760
01D5 0  A80D       465            D       RAWN                               HWE03770
01D6 0  D21E       466            STO  2  VT157                              HWE03780
01D7 01 74FF0141   467            MDM     TRIMS,-1                           HWE03790
01D9 0  7042       468            MDX     ENDTM                              HWE03800
                   469      *                                                HWE03810
01DA 0  701A       470            B       LORG1                              HWE03820
                   471      *                                                HWE03830
01DC    0000       472            BSS  E  0                                  HWE03840
01DC 0  0000       473            DC      *-*                                HWE03850
01DD 0  0000       474      TEMP2 DC      *-*                                HWE03860
01DE               475            ORG     *-1                                HWE03870
01DD 9A 5DD77000   476            XFLC    4.92E7                             HWE03880
01DE               477      KSUBN EQU     TEMP2+1                            HWE03890
                   478      *                ENGINE SPEED                    HWE03900
01E0    0000       479      RPM   BSS  E  0                                  HWE03910
01E0 0  0000       480            DC      0                                  HWE03920
01E1 0  5F41       481            DC      /5F41                              HWE03930
01E2 0  0000       482      TESTN DC      *-*                                HWE03940
01E3 0  0000       483      RAWN  DC      *-*                                HWE03950
                   484            LORG                                       HWE03960
01E4 0  7F80       485      +     DC      /7F80
01E5 0  007F       486      +     DC      127
01E6 0  8000       487      +     DC      /8000
01E7 0  7FFF       488      +     DC      /7FFF
01E8 0  4000       489      +     DC      /4000
01E9 0  2000       490      +     DC      /2000
01EA 0  005A       491      +     DC      90
01EB 0  0000       492      +     DC      0
01EC 0  1000       493      +     DC      /1000
01ED 0  0800       494      +     DC      /0800
01EE 0  0400       495      +     DC      /0400
01EF 0  00FF       496      +     DC      /00FF
01F0 0  00AA       497      +     DC      /00AA
01F1 0  EC78       498      +     DC      -5000
01F2 0  1B58       499      +     DC      7000
01F3 0  0055       500      +     DC      /0055
01F4 0  000A       501      +     DC      10
01F5               502      LORG1 EQU     *                                  HWE03970
                   503      *                                                HWE03980
                   504      *         ANALOG VOLTAGE ADJUSTMENTS             HWE03990
                   505      *                STRIP 3                         HWE04000
01F5 0  C312       506      ANALT LD   3  P18                                HWE04010
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Table B-13. Bendix Bounds Program (Continued)


```
01F6 0  D292       507          STO   2 VT110                                          HWE04020
01F7 0  C313       508          LD    3 P19                                            HWE04030
01F8 0  D291       509          STO   2 VT111                                          HWE04040
01F9 0  C314       510          LD    3 P20                                            HWE04050
01FA 0  D290       511          STO   2 VT112                                          HWE04060
01FB 0  C315       512          LD    3 P21                                            HWE04070
01FC 0  D28F       513          STO   2 VT113                                          HWE04080
01FD 0  C316       514          LD    3 P22                                            HWE04090
01FE 0  D28E       515          STO   2 VT114                                          HWE04100
01FF 0  C317       516          LD    3 P23                                            HWE04110
0200 0  D28D       517          STO   2 VT115                                          HWE04120
0201 0  C318       518          LD    3 P24                                            HWE04130
0202 0  D28C       519          STO   2 VT116                                          HWE04140
0203 0  C319       520          LD    3 P25                                            HWE04150
0204 0  D28B       521          STO   2 VT117                                          HWE04160
0205 0  C31A       522          LD    3 P26                                            HWE04170
0206 0  D28A       523          STO   2 VT118                                          HWE04180
                   524     *                        STRIP 4                            HWE04190
0207 0  C31B       525          LD    3 P27                                            HWE04200
0208 0  D289       526          STO   2 VT119                                          HWE04210
0209 0  C31C       527          LD    3 P28                                            HWE04220
020A 0  D288       528          STO   2 VT120                                          HWE04230
020B 0  C31D       529          LD    3 P29                                            HWE04240
020C 0  D287       530          STO   2 VT121                                          HWE04250
020D 0  C31E       531          LD    3 P30                                            HWE04260
020E 0  D286       532          STO   2 VT122                                          HWE04270
020F 0  C31F       533          LD    3 P31                                            HWE04280
0210 0  D285       534          STO   2 VT123                                          HWE04290
0211 0  C320       535          LD    3 P32                                            HWE04300
0212 0  D284       536          STO   2 VT124                                          HWE04310
0213 0  C321       537          LD    3 P33                                            HWE04320
0214 0  D283       538          STO   2 VT125                                          HWE04330
0215 0  C322       539          LD    3 P34                                            HWE04340
0216 0  D282       540          STO   2 VT126                                          HWE04350
0217 0  C323       541          LD    3 P35                                            HWE04360
0218 0  D281       542          STO   2 VT127                                          HWE04370
0219 0  C050       543          LD      =50                                            HWE04380
021A 01 D4000141   544          STO   L TRIMS                                          HWE04390
021C               545     ENDTM EQU     *                                             HWE04400
                   546     *                        STRIP 5                            HWE04410
021C 0  C324       547          LD    3 P36                 DP/P                  EK14 HWE04420
021D 0  D264       548          STO   2 VT227                                          HWE04430
021E 0  C325       549          LD    3 P37                           SPARE            HWE04440
021F 0  D265       550          STO   2 VT228                                          HWE04450
0220 0  C326       551          LD    3 P38                           SPARE            HWE04460
0221 0  D266       552          STO   2 VT229                                          HWE04470
0222 0  C327       553          LD    3 P39                 P3                    EK14 HWE04480
0223 0  D267       554          STO   2 VT230                                          HWE04490
0224 0  C328       555          LD    3 P40                 PB                    EK15 HWE04500
0225 0  D268       556          STO   2 VT231                                          HWE04510
0226 0  A054       557          M       =20000                                         HWE04520
0227 0  1081       558          SLT     1                                              HWE04530
0228 0  D29A       559          STO   2 VT102          PB=100XPSI                      HWE04540
0229 0  C329       560          LD    3 P41                 DP                    EK15 HWE04550
022A 0  D269       561          STO   2 VT232                                          HWE04560
022B 0  A050       562          M       =30000                                         HWE04570
022C 0  1081       563          SLT     1                                              HWE04580
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Table B-13. Bendix Bounds Program (Continued)


```
022D 0  D299      564      STO   2 VT103     DP=1000XPSI             HWE04590
022E 0  C32A      565      LD    3 P42              P2          EK15 HWE04600
022F 0  D26A      566      STO   2 VT233                               HWE04610
0230 0  A04C      567      M       =25000                              HWE04620
0231 0  1081      568      SLT     1                                   HWE04630
0232 0  D298      569      STO   2 VT104     P2=1000XPSI               HWE04640
0233 0  C32B      570      LD    3 P43              P23-P2      EK15 HWE04650
0234 0  D26B      571      STO   2 VT234                               HWE04660
0235 0  A048      572      M       =15000                              HWE04670
0236 0  D297      573      STO   2 VT105     P23-P2=100XPSI            HWE04680
0237 0  C32C      574      LD    3 P44              POSITION    EK15 HWE04690
0238 0  D26C      575      STO   2 VT235                               HWE04700
                  576  *                     STRIP 6                   HWE04710
0239 0  C32D      577      LD    3 P45              N ANALOG    EK15 HWE04720
023A 0  D26D      578      STO   2 VT236                               HWE04730
023B 0  C32E      579      LD    3 P46              P24-P2      EK15 HWE04740
023C 0  D26E      580      STO   2 VT237                               HWE04750
023D 0  A040      581      M       =15000                              HWE04760
023E 0  D296      582      STO   2 VT106     P24-P2=100XPSI            HWE04770
023F 0  C32F      583      LD    3 P47              P25-P2      EK15 HWE04780
0240 0  D26F      584      STO   2 VT238                               HWE04790
0241 0  A03C      585      M       =15000                              HWE04800
0242 0  D295      586      STO   2 VT107     P25-P2=100XPSI            HWE04810
0243 0  C330      587      LD    3 P48              P5          EK15 HWE04820
0244 0  D270      588      STO   2 VT239                               HWE04830
0245 0  A039      589      M       =10000                              HWE04840
0246 0  D294      590      STO   2 VT108     P5=100XPSI                HWE04850
0247 0  C331      591      LD    3 P49              P0          EK15 HWE04860
0248 0  D271      592      STO   2 VT240                               HWE04870
0249 0  A033      593      M       =25000                              HWE04880
024A 0  1081      594      SLT     1                                   HWE04890
024B 0  D293      595      STO   2 VT109     P0=1000 PSI               HWE04900
024C 0  C332      596      LD    3 P50         P/P        EK15         HWE04910
024D 0  D272      597      STO   2 VT241                               HWE04920
024E 0  C333      598      LD    3 P51                          EK15 HWE04930
024F 0  D273      599      STO   2 VT242                               HWE04940
0250 0  C334      600      LD    3 P52                          EK15 HWE04950
0251 0  D274      601      STO   2 VT243                               HWE04960
0252 0  C335      602      LD    3 P53                          EK15 HWE04970
0253 0  D275      603      STO   2 VT244                               HWE04980
                  604  *                     STRIP 7                   HWE04990
0254 0  C336      605      LD    3 P54              T2          EK18 HWE05000
0255 0  802A      606      A       =19520                              HWE05010
0256 0  D276      607      STO   2 VT245                               HWE05020
0257 0  A029      608      M       =20480                              HWE05030
0258 0  9029      609      S       =4600                               HWE05040
0259 0  D2A1      610      STO   2 VT095     T2=10XF                   HWE05050
025A 0  C337      611      LD    3 P55              T3          EK18 HWE05060
025B 0  8024      612      A       =19520                              HWE05070
025C 0  D277      613      STO   2 VT246                               HWE05080
025D 0  A023      614      M       =20480                              HWE05090
025E 0  9023      615      S       =4600                               HWE05100
025F 0  D2A0      616      STO   2 VT096     T3=10XF                   HWE05110
0260 0  C338      617      LD    3 P56              T4          EK18 HWE05120
0261 01 A4000283  618      M     L =4000
0263 01 AC000284  619      D     L =10813
0265 01 84000285  620      A     L =1645
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Table B-13. Bendix Bounds Program (Continued)


```
0267 0  D29F     621            STO   2 VT097      T4=10XF                     HWE05160
0268 0  C339     622            LD    3 P57           T5                  EK18 HWE05170
0269 0  801C     623            A       =6100                                  HWE05180
026A 0  D279     624            STO   2 VT248                                  HWE05190
026B 0  9016     625            S       =4600                                  HWE05200
026C 0  D29E     626            STO   2 VT098      T5=10XF                     HWE05210
026D 0  C33A     627            LD    3 P58                 PLA1          EK18 HWE05220
026E 0  D27A     628            STO   2 VT249                                  HWE05230
026F 0  C33B     629            LD    3 P59                 PLA2          EK18 HWE05240
0270 0  D27B     630            STO   2 VT250                                  HWE05250
0271 0  C33C     631            LD    3 P60                 LEAD-LAG SIGNAL  EK18 HWE05260
0272 0  D27C     632            STO   2 VT251                                  HWE05270
0273 0  C33D     633            LD    3 P61                               EK18 HWE05280
0274 0  D27D     634            STO   2 VT252                                  HWE05290
0275 0  C33E     635            LD    3 P62                               EK18 HWE05300
0276 0  D27E     636            STO   2 VT253                                  HWE05310
                 637      *                        64TH POINT                  HWE05320
0277 0  C33F     638            LD    3 P63                                    HWE05330
0278 0  D27F     639            STO   2 VT254                                  HWE05340
0279 0  700D     640            B       GOTO1                                  HWE05350
                 641            LORG                                           HWE05360
027A 0  0032     642      +     DC      50
027B 0  4E20     643      +     DC      20000
027C 0  7530     644      +     DC      30000
027D 0  61A8     645      +     DC      25000
027E 0  3A98     646      +     DC      15000
027F 0  2710     647      +     DC      10000
0280 0  4C40     648      +     DC      19520
0281 0  5000     649      +     DC      20480
0282 0  11F8     650      +     DC      4600
0283 0  0FA0     651      +     DC      4000
0284 0  2A3D     652      +     DC      10813
0285 0  066D     653      +     DC      1645
0286 0  17D4     654      +     DC      6100
0287             655      GOTO1 EQU     *                                      HWE05370
                 656      *                      POWER REQUEST                 HWE05380
0287 0  C2FF     657            LD    2 VT001      IDLE SPEED TRIM             HWE05390
0288 0  1883     658            SRT     3                                      HWE05400
0289 0  806E     659            A       =7950                                  HWE05410
028A 0  D218     660            STO   2 VT151                                  HWE05420
028B 0  C2FE     661            LD    2 VT002      MAX SPEED TRIM              HWE05430
028C 0  1883     662            SRT     3                                      HWE05440
028D 0  8068     663            A       =16542                                 HWE05450
028E 0  D219     664            STO   2 VT152                                  HWE05460
028F 0  C27A     665            LD    2 VT249      POWER LEVER                 HWE05470
0290 0  1881     666            SRT     1                                      HWE05480
0291 0  8068     667            A       =7212                                  HWE05490
0292 0  D217     668            STO   2 VT150                                  HWE05500
                 669      *  SELECT HIGH                                       HWE05510
0293 0  B218     670            CMP   2 VT151                                  HWE05520
0294 0  7002     671            MDX     *+2                                    HWE05530
0295 0  1000     672            NOP                                            HWE05540
0296 0  C218     673            LD    2 VT151                                  HWE05550
                 674      *  SELECT LOW                                        HWE05560
0297 0  B219     675            CMP   2 VT152                                  HWE05570
0298 0  C219     676            LD    2 VT152                                  HWE05580
0299 0  1000     677            NOP                                            HWE05590
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Table B-13. Bendix Bounds Program (Continued)


```
029A 0  D201         678            STO   2 VT126                                      HWE05600
029B 0  C2FC         679            LD    2 VT004                                      HWE05610
029C 0  905E         680            S       =64                                        HWE05620
029D 01 4C2802C2     681            BN      SAM1                                       HWE05630
029F 0  C2FB         682            LD    2 VT005                                      HWE05640
02A0 0  1889         683            SRT     9                                          HWE05650
02A1 0  D206         684            STO   2 VT133                                      HWE05660
02A2 0  C2FA         685            LD    2 VT006                                      HWE05670
02A3 0  A268         686            M     2 VT231                                      HWE05680
02A4 0  1886         687            SRT     6                                          HWE05690
                     688      *  SELECT HIGH                                           HWE05700
02A5 0  B206         689            CMP   2 VT133                                      HWE05710
02A6 0  7002         690            MDX     *+2                                        HWE05720
02A7 0  1000         691            NOP                                                HWE05730
02A8 0  C206         692            LD    2 VT133                                      HWE05740
02A9 0  D21A         693            STO   2 VT153                                      HWE05750
02AA 0  C2F9         694            LD    2 VT007                                      HWE05760
02AB 0  1889         695            SRT     9                                          HWE05770
02AC 0  D207         696            STO   2 VT134                                      HWE05780
02AD 0  C2F8         697            LD    2 VT008                                      HWE05790
02AE 0  A268         698            M     2 VT231                                      HWE05800
02AF 0  1886         699            SRT     6                                          HWE05810
                     700      *  SELECT LOW                                            HWE05820
02B0 0  B207         701            CMP   2 VT134                                      HWE05830
02B1 0  C207         702            LD    2 VT134                                      HWE05840
02B2 0  1000         703            NOP                                                HWE05850
02B3 0  D21B         704            STO   2 VT154                                      HWE05860
02B4 0  C201         705            LD    2 VT128                                      HWE05870
02B5 0  9205         706            S     2 VT132                                      HWE05880
02B6 0  D202         707            STO   2 VT129                                      HWE05890
                     708      *  SELECT LOW                                            HWE05900
02B7 0  B21A         709            CMP   2 VT153                                      HWE05910
02B8 0  C21A         710            LD    2 VT153                                      HWE05920
02B9 0  1000         711            NOP                                                HWE05930
02BA 0  D203         712            STO   2 VT130                                      HWE05940
                     713      *  SELECT HIGH                                           HWE05950
02BB 0  B21B         714            CMP   2 VT154                                      HWE05960
02BC 0  7002         715            MDX     *+2                                        HWE05970
02BD 0  1000         716            NOP                                                HWE05980
02BE 0  C21B         717            LD    2 VT154                                      HWE05990
02BF 0  D204         718            STO   2 VT131                                      HWE06000
02C0 0  8205         719            A     2 VT132                                      HWE06010
02C1 0  7001         720            B       SAM2                                       HWE06020
02C2 0  C201         721      SAM1  LD    2 VT128                                      HWE06030
02C3 0  D205         722      SAM2  STO   2 VT132                                      HWE06040
02C4 0  C276         723            LD    2 VT245                                      HWE06050
02C5 0  9036         724            S       =12640                                     HWE06060
02C6 0  A0BA         725            M       =20480                                     HWE06070
02C7 0  1081         726            SLT     1                                          HWE06080
02C8 0  8034         727            A       =15542                                     HWE06090
02C9 0  D21C         728            STO   2 VT155                                      HWE06100
                     729      *  SELECT LOW                                            HWE06110
02CA 0  B205         730            CMP   2 VT132                                      HWE06120
02CB 0  C205         731            LD    2 VT132                                      HWE06130
02CC 0  1000         732            NOP                                                HWE06140
02CD 0  D21D         733            STO   2 VT156                                      HWE06150
                     734      *                          SPEED CONTROL                 HWE06160
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Table B-13. Bendix Rounds Program (Continued)


```
02CE 0  C02F                       LD        =-1600                                  HWE06170
                         *                             SELECT LOW                    HWE06180
02CF 0  826D                       CMP    2  VT236                                   HWE06190
02D0 0  C26D                       LD     2  VT236                                   HWE06200
02D1 0  1000                       NOP                                               HWE06210
02D2 0  821E                       A      2  VT157                                   HWE06220
02D3 01 4C2802D9                   BN        NEG1     SPEED                          HWE06230
02D5 0  9029                       S         =800     COMPARISON                     HWE06240
02D6 01 4C3002DC                   BP        POS1                                    HWE06250
02D8 0  7007                       B         SAM3                                    HWE06260
02D9 0  8025             NEG1      A         =800                                    HWE06270
02DA 01 4C3002E0                   BP        SAM3                                    HWE06280
02DC 0  C26A             POS1      LD     2  VT233                                   HWE06290
02DD 0  A022                       M         =8873                                   HWE06300
02DE 0  1080                       SLT       0                                       HWE06310
02DF 0  7001                       B         SAM4                                    HWE06320
02E0 0  C020             SAM3      LD        =21000                                  HWE06330
02E1 0  D21F             SAM4      STO    2  VT158                                   HWE06340
                         *                                                           HWE06350
02E2 0  C2F7                       LD     2  VT009                                   HWE06360
02E3 0  801E                       A         =-123                                   HWE06370
02E4 01 4C3002F3                   BP        NOUT                                    HWE06380
02E6 0  C01A                       LD        =21000                                  HWE06390
02E7 0  D235                       STO    2  VT180     INPUT POINT OF VALVE POS      HWE06400
02E8 0  C21D                       LD     2  VT156                                   HWE06410
02E9 0  921E                       S      2  VT157                                   HWE06420
02EA 0  D220                       STO    2  VT159                                   HWE06430
02EB 0  A2FD                       M      2  VT003                                   HWE06440
02EC 0  1082                       SLT       2                                       HWE06450
02ED 0  D221                       STO    2  VT160                                   HWE06460
02EE 0  C2F6                       LD     2  VT010                                   HWE06470
02EF 0  1882                       SRT       2                                       HWE06480
02F0 0  8221                       A      2  VT160                                   HWE06490
02F1 0  D222                       STO    2  VT161                                   HWE06500
02F2 0  7004                       B         WFP3                                    HWE06510
                         *
                         *
                         *                             ****************************
                         *                             ****************************
                         *
                         *                             CALL HONEYWELL CONTROL PROG
02F3 0  C087             NOUT      LD        =20000                                  HWE06520
02F4 0  D222                       STO    2  VT161                                   HWE06530
02F5 30 089850E3                   CALL      HWECT
                         *                             ****************************
                         *                             ****************************
                         *
                         *
                         *
                         *
02F7                     WFP3      EQU       *                                       HWE06540
02F7 0  700B                       B         GOTO2                                   HWE06550
                                   LORG                                              HWE06560
02F8 0  1F0E             +         DC        7950
02F9 0  409E             +         DC        16542
02FA 0  1C2C             +         DC        7212
02FB 0  0040             +         DC        64
```

Table B-13. Bendix Bounds Program (Continued)


```
02FC 0  3160       792  +         DC      12640
02FD 0  3CB6       793  +         DC      15542
02FE 0  F9C0       794  +         DC      -1600
02FF 0  0320       795  +         DC      800
0300 0  22A9       796  +         DC      8873
0301 0  5208       797  +         DC      21000
0302 0  FF85       798  +         DC      -123
0303               799  GOTO2     EQU     *                                      HWE06570
                   800  *                         THIS FOLLOWS BEN06220          HWE06580
                   801  *                         TEMPERATURE TRACK COMPUTE      HWE06590
0303 0  C276       802            LD      2  VT245  T2                           HWE06600
0304 0  9064       803            S          =18320 112.5 DEGREES F              HWE06610
0305 01 4C300422   804            BP      L  T2125                               HWE06620
0307 0  80F7       805            A          =800   25 DEG F                     HWE06630
0308 01 4C3003E1   806            BP      L  T2100                               HWE06640
030A 0  80F4       807            A          =800                                HWE06650
030B 01 4C3003B6   808            BP      L  T275                                HWE06660
030D 0  80F1       809            A          =800                                HWE06670
030E 01 4C300381   810            BP      L  T250                                HWE06680
0310 0  80EE       811            A          =800                                HWE06690
0311 01 4C30033E   812            BP         T225                                HWE06700
                   813  *                         ZERO DEGREES F TRACK           HWE06710
0313 0  C2E7       814            LD      2  VT025                               HWE06720
0314 0  1885       815            SRT        5                                   HWE06730
0315 0  8054       816            A          =15715                              HWE06740
0316 0  921E       817            S       2  VT157                               HWE06750
0317 01 4C30031E   818            BP         PATH4                               HWE06760
0319 0  A051       819            M          =24800                              HWE06770
031A 0  1084       820            SLT        4                                   HWE06780
031B 0  8050       821            A          =19500                              HWE06790
031C 01 4C00044D   822            B       L  MAXWP                               HWE06800
031E 0  C04E       823  PATH4     LD         =13234                              HWE06810
031F 0  921E       824            S       2  VT157                               HWE06820
0320 01 4C300327   825            BP         PATH3                               HWE06830
0322 0  A048       826            M          =0                                  HWE06840
0323 0  1084       827            SLT        4                                   HWE06850
0324 0  8047       828            A          =19500                              HWE06860
0325 01 4C00044D   829            B       L  MAXWP                               HWE06870
0327 0  9047       830  PATH3     S          =3561                               HWE06880
0328 01 4C30032F   831            BP         PATH2                               HWE06890
032A 0  A045       832            M          =-6320                              HWE06900
032B 0  1084       833            SLT        4                                   HWE06910
032C 0  8044       834            A          =14000                              HWE06920
032D 01 4C00044D   835            B       L  MAXWP                               HWE06930
032F 0  9042       836  PATH2     S          =4710                               HWE06940
0330 01 4C300337   837            BP         PATH1                               HWE06950
0332 0  A040       838            M          =1730                               HWE06960
0333 0  1084       839            SLT        4                                   HWE06970
0334 0  803F       840            A          =16000                              HWE06980
0335 01 4C00044D   841            B       L  MAXWP                               HWE06990
0337 0  C03C       842  PATH1     LD         =16000                              HWE07000
0338 0  92E8       843            S       2  VT024                               HWE07010
0339 0  A21E       844            M       2  VT157                               HWE07020
033A 0  A83A       845            D          =4963                               HWE07030
033B 0  82E8       846            A       2  VT024                               HWE07040
033C 01 4C00044D   847            B       L  MAXWP                               HWE07050
                   848  *                         25 DEGREES F TRACK             HWE07060
```

Table B-13. Bendix Bounds Program (Continued)


```
033E 0  C2E7      849  T225   LD     2 VT025      HWE07070
033F 0  1885      850         SRT      5          HWE07080
0340 0  8035      851         A        =15797     HWE07090
0341 0  921E      852         S      2 VT157      HWE07100
0342 01 4C300349  853         BP       PTH14      HWE07110
0344 0  A026      854         M        =24800     HWE07120
0345 0  1084      855         SLT      4          HWE07130
0346 0  8030      856         A        =19000     HWE07140
0347 01 4C00044D  857         B      L MAXWP      HWE07150
0349 0  C023      858  PTH14  LD       =13234     HWE07160
034A 0  921E      859         S      2 VT157      HWE07170
034B 01 4C300352  860         BP       PTH13      HWE07180
034D 0  A02A      861         M        =399       HWE07190
034E 0  1084      862         SLT      4          HWE07200
034F 0  8029      863         A        =19250     HWE07210
0350 01 4C00044D  864         B      L MAXWP      HWE07220
0352 0  9027      865  PTH13  S        =3309      HWE07230
0353 01 4C30035A  866         BP       PTH12      HWE07240
0355 0  A025      867         M        =-5870     HWE07250
0356 0  1084      868         SLT      4          HWE07260
0357 0  8024      869         A        =14250     HWE07270
0358 01 4C00044D  870         B      L MAXWP      HWE07280
035A 0  9022      871  PTH12  S        =4549      HWE07290
035B 01 4C300362  872         BP       PTH11      HWE07300
035D 0  A020      873         M        =1570      HWE07310
035E 0  1084      874         SLT      4          HWE07320
035F 0  801F      875         A        =16250     HWE07330
0360 01 4C00044D  876         B      L MAXWP      HWE07340
0362 0  C01C      877  PTH11  LD       =16250     HWE07350
0363 0  92E8      878         S      2 VT024      HWE07360
0364 0  A21E      879         M      2 VT157      HWE07370
0365 0  A81A      880         D        =5376      HWE07380
0366 0  82E8      881         A      2 VT024      HWE07390
0367 01 4C00044D  882         B      L MAXWP      HWE07400
                  883         LORG                HWE07410
0369 0  4790      884  +      DC       18320
036A 0  3D63      885  +      DC       15715
036B 0  60E0      886  +      DC       24800
036C 0  4C2C      887  +      DC       19500
036D 0  33B2      888  +      DC       13234
036E 0  0000      889  +      DC       0
036F 0  0DE9      890  +      DC       3561
0370 0  E750      891  +      DC       -6320
0371 0  36B0      892  +      DC       14000
0372 0  1266      893  +      DC       4710
0373 0  06C2      894  +      DC       1730
0374 0  3E80      895  +      DC       16000
0375 0  1363      896  +      DC       4963
0376 0  3DB5      897  +      DC       15797
0377 0  4A38      898  +      DC       19000
0378 0  018F      899  +      DC       399
0379 0  4B32      900  +      DC       19250
037A 0  0CED      901  +      DC       3309
037B 0  E912      902  +      DC       -5870
037C 0  37AA      903  +      DC       14250
037D 0  11C5      904  +      DC       4549
037E 0  0622      905  +      DC       1570
```

Table B-13. Bendix Bounds Program (Continued)


```
037F 0  3F7A      906  +        DC      16250
0380 0  1500      907  +        DC      5376
                  908  *                         50 DEGREE TRACK        HWE07420
0381 0  C2E7      909  T250     LD.   2 VT025                           HWE07430
0382 0  1885      910           SRT     5                               HWE07440
0383 0  8028      911           A       =15879                          HWE07450
0384 0  921E      912           S     2 VT157                           HWE07460
0385 01 4C30038C  913           BP      PTH24                           HWE07470
0387 0  A0E3      914           M       =24800                          HWE07480
0388 0  1084      915           SLT     4                               HWE07490
0389 0  8023      916           A       =18500                          HWE07500
038A 01 4C00044D  917           B     L MAXWP                           HWE07510
038C 0  C0E0      918  PTH24    LD      =13234                          HWE07520
038D 0  921E      919           S     2 VT157                           HWE07530
038E 01 4C300395  920           BP      PTH23                           HWE07540
0390 0  A01D      921           M       =774                            HWE07550
0391 0  1084      922           SLT     4                               HWE07560
0392 0  80E4      923           A       =19000                          HWE07570
0393 01 4C00044D  924           B     L MAXWP                           HWE07580
0395 0  9019      925  PTH23    S       =3071                           HWE07590
0396 01 4C30039D  926           BP      PTH22                           HWE07600
0398 0  A017      927           M       =-5330                          HWE07610
0399 0  1084      928           SLT     4                               HWE07620
039A 0  8016      929           A       =15000                          HWE07630
039B 01 4C00044D  930           B     L MAXWP                           HWE07640
039D 0  9014      931  PTH22    S       =4373                           HWE07650
039E 01 4C3003A5  932           BP      PTH21                           HWE07660
03A0 0  A012      933           M       =1404                           HWE07670
03A1 0  1084      934           SLT     4                               HWE07680
03A2 0  8011      935           A       =16500                          HWE07690
03A3 01 4C00044D  936           B     L MAXWP                           HWE07700
03A5 0  C00E      937  PTH21    LD      =16500                          HWE07710
03A6 0  92E8      938           S     2 VT024                           HWE07720
03A7 0  A21E      939           M     2 VT157                           HWE07730
03A8 0  A80C      940           D       =5790                           HWE07740
03A9 0  82E8      941           A     2 VT024                           HWE07750
03AA 01 4C00044D  942           B     L MAXWP                           HWE07760
                  943           LORG                                    HWE07770
03AC 0  3E07      944  +        DC      15879
03AD 0  4844      945  +        DC      18500
03AE 0  0306      946  +        DC      774
03AF 0  0BFF      947  +        DC      3071
03B0 0  EB2E      948  +        DC      -5330
03B1 0  3A98      949  +        DC      15000
03B2 0  1115      950  +        DC      4373
03B3 0  057C      951  +        DC      1404
03B4 0  4074      952  +        DC      16500
03B5 0  169E      953  +        DC      5790
                  954  *                         75 DEGREE F TRACK      HWE07780
03B6 0  C2E7      955  T275     LD    2 VT025                           HWE07790
03B7 0  1885      956           SRT     5                               HWE07800
03B8 0  8054      957           A       =15961                          HWE07810
03B9 0  921E      958           S     2 VT157                           HWE07820
03BA 01 4C3003C1  959           BP      PTH34                           HWE07830
03BC 0  A0AE      960           M       =24800                          HWE07840
03BD 0  1084      961           SLT     4                               HWE07850
03BE 0  804F      962           A       =18000                          HWE07860
```

Table B-13. Bendix Bounds Program (Continued)


```
03BF 01 4C00044D   963          B      L  MAXWP                      HWE07870
03C1 0  C0AB       964   PTH34  LD        =13234                     HWE07880
03C2 0  921E       965          S      2  VT157                      HWE07890
03C3 01 4C3003CA   966          BP        PTH33                      HWE07900
03C5 0  A049       967          M         =1127                      HWE07910
03C6 0  1084       968          SLT       4                          HWE07920
03C7 0  8048       969          A         =18750                     HWE07930
03C8 01 4C00044D   970          B      L  MAXWP                      HWE07940
03CA 0  9046       971   PTH33  S         =2823                      HWE07950
03CB 01 4C3003D2   972          BP        PTH32                      HWE07960
03CD 0  A044       973          M         =-4710                     HWE07970
03CE 0  1084       974          SLT       4                          HWE07980
03CF 0  8043       975          A         =15500                     HWE07990
03D0 01 4C00044D   976          B      L  MAXWP                      HWE08000
03D2 0  9041       977   PTH32  S         =4208                      HWE08010
03D3 01 4C3003DA   978          BP        PTH31                      HWE08020
03D5 0  A03F       979          M         =1215                      HWE08030
03D6 0  1084       980          SLT       4                          HWE08040
03D7 0  803E       981          A         =16750                     HWE08050
03D8 01 4C00044D   982          B      L  MAXWP                      HWE08060
03DA 0  C03B       983   PTH31  LD        =16750                     HWE08070
03DB 0  92E8       984          S      2  VT024                      HWE08080
03DC 0  A21E       985          M      2  VT157                      HWE08090
03DD 0  AB39       986          D         =6203                      HWE08100
03DE 0  82E8       987          A      2  VT024                      HWE08110
03DF 01 4C00044D   988          B      L  MAXWP                      HWE08120
                   989   *                    100 DEGREE F TRACK     HWE08130
03E1 0  C2E7       990   T2100  LD     2  VT025                      HWE08140
03E2 0  1885       991          SRT       5                          HWE08150
03E3 0  8034       992          A         =16045                     HWE08160
03E4 0  921E       993          S      2  VT157                      HWE08170
03E5 01 4C3003EC   994          BP        PTH44                      HWE08180
03E7 0  A083       995          M         =24800                     HWE08190
03E8 0  1084       996          SLT       4                          HWE08200
03E9 0  802F       997          A         =17500                     HWE08210
03EA 01 4C00044D   998          B      L  MAXWP                      HWE08220
03EC 01 C400036D   999   PTH44  LD     L  =13234                     HWE08230
03EE 0  921E      1000          S      2  VT157                      HWE08240
03EF 01 4C3003F6  1001          BP        PTH43                      HWE08250
03F1 0  A028      1002          M         =1455                      HWE08260
03F2 0  1084      1003          SLT       4                          HWE08270
03F3 0  80B9      1004          A         =18500                     HWE08280
03F4 01 4C00044D  1005          B      L  MAXWP                      HWE08290
03F6 0  9024      1006   PTH43  S         =2573                      HWE08300
03F7 01 4C3003FE  1007          BP        PTH42                      HWE08310
03F9 0  A022      1008          M         =-3980                     HWE08320
03FA 0  1084      1009          SLT       4                          HWE08330
03FB 0  8021      1010          A         =16000                     HWE08340
03FC 01 4C00044D  1011          B      L  MAXWP                      HWE08350
03FE 0  901F      1012   PTH42  S         =4042                      HWE08360
03FF 01 4C300406  1013          BP        PTH41                      HWE08370
0401 0  A01D      1014          M         =1012                      HWE08380
0402 0  1084      1015          SLT       4                          HWE08390
0403 0  801C      1016          A         =17000                     HWE08400
0404 01 4C00044D  1017          B      L  MAXWP                      HWE08410
0406 0  C019      1018   PTH41  LD        =17000                     HWE08420
0407 0  92E8      1019          S      2  VT024                      HWE08430
```

Table B-13. Bendix Bounds Program (Continued)


```
0408 0  A21E      1020          M      2 VT157                                   HWE08440
0409 0  A817      1021          D        =6617                                   HWE08450
040A 0  82E8      1022          A      2 VT024                                   HWE08460
040B 01 4C00044D  1023          B      L MAXWP                                   HWE08470
                  1024          LORG                                             HWE08480
040D 0  3E59      1025   +      DC       15961
040E 0  4650      1026   +      DC       18000
040F 0  0467      1027   +      DC       1127
0410 0  493E      1028   +      DC       18750
0411 0  0B07      1029   +      DC       2823
0412 0  ED9A      1030   +      DC       -4710
0413 0  3C8C      1031   +      DC       15500
0414 0  1070      1032   +      DC       4208
0415 0  04BF      1033   +      DC       1215
0416 0  416E      1034   +      DC       16750
0417 0  183B      1035   +      DC       6203
0418 0  3EAD      1036   +      DC       16045
0419 0  445C      1037   +      DC       17500
041A 0  05AF      1038   +      DC       1455
041B 0  0A0D      1039   +      DC       2573
041C 0  F074      1040   +      DC       -3980
041D 0  3E80      1041   +      DC       16000
041E 0  0FCA      1042   +      DC       4042
041F 0  03F4      1043   +      DC       1012
0420 0  4268      1044   +      DC       17000
0421 0  19D9      1045   +      DC       6617
                  1046   *                          125 DEGREE F TRACK           HWE08490
0422 0  C2E7      1047   T2125  LD     2 VT025                                   HWE08500
0423 0  1885      1048          SRT      5                                       HWE08510
0424 0  904C      1049          A        =16128                                  HWE08520
0425 0  921E      1050          S      2 VT157                                   HWE08530
0426 01 4C30042D  1051          BP       PTH54                                   HWE08540
0428 0  A049      1052          M        =24800                                  HWE08550
0429 0  1084      1053          SLT      4                                       HWE08560
042A 0  80F5      1054          A        =17000                                  HWE08570
042B 01 4C00044D  1055          B      L MAXWP                                   HWE08580
042D 0  C045      1056   PTH54  LD       =13234                                  HWE08590
042E 0  921E      1057          S      2 VT157                                   HWE08600
042F 01 4C300436  1058          BP       PTH53                                   HWE08610
0431 0  A042      1059          M        =1769                                   HWE08620
0432 0  1084      1060          SLT      4                                       HWE08630
0433 0  8041      1061          A        =18250                                  HWE08640
0434 01 4C00044D  1062          B      L MAXWP                                   HWE08650
0436 0  903F      1063   PTH53  S        =2327                                   HWE08660
0437 01 4C30043E  1064          BP       PTH52                                   HWE08670
0439 0  A030      1065          M        =-3080                                  HWE08680
043A 0  1084      1066          SLT      4                                       HWE08690
043B 0  803C      1067          A        =16500                                  HWE08700
043C 01 4C00044D  1068          B      L MAXWP                                   HWE08710
043E 0  903A      1069   PTH52  S        =3877                                   HWE08720
043F 01 4C300446  1070          BP       PTH51                                   HWE08730
0441 0  A038      1071          M        =792                                    HWE08740
0442 0  1084      1072          SLT      4                                       HWE08750
0443 0  8037      1073          A        =17250                                  HWE08760
0444 01 4C00044D  1074          B      L MAXWP                                   HWE08770
0446 0  C034      1075   PTH51  LD       =17250                                  HWE08780
0447 0  92E8      1076          S      2 VT024                                   HWE08790
```

Table B-13. Bendix Bounds Program (Continued)


```
0448 0  A21E       1077           M     2 VT157                           HWE08800
0449 0  A832       1078           D       =7030                           HWE08810
044A 0  82E8       1079           A     2 VT024                           HWE08820
044B 01 4C00044D   1080           B     L MAXWP                           HWE08830
044D 0  1882       1081   MAXWP   SRT     2                               HWE08840
044E 0  D236       1082           STO   2 VT181                           HWE08850
                   1083   *                      MINIMUM RATIOS COMPUTATION HWE08860
044F 0  C2E2       1084           LD    2 VT030                           HWE08870
0450 0  1882       1085           SRT     2                               HWE08880
0451 0  D20D       1086           STO   2 VT140                           HWE08890
0452 0  C21E       1087           LD    2 VT157                           HWE08900
0453 0  9029       1088           S       =7100                           HWE08910
0454 0  A2E3       1089           M     2 VT029                           HWE08920
0455 0  1881       1090           SRT     1                               HWE08930
0456 0  820D       1091           A     2 VT140                           HWE08940
0457 0  1882       1092           SRT     2                               HWE08950
0458 0  D23F       1093           STO   2 VT190                           HWE08960
                   1094   *                      SELECT HIGH              HWE08970
0459 0  C21E       1095           LD    2 VT157                           HWE08980
045A 0  B022       1096           CMP     =7100                           HWE08990
045B 0  7002       1097           MDX     *+2                             HWE09000
045C 0  1000       1098           NOP                                     HWE09010
045D 0  C01F       1099           LD      =7100                           HWE09020
045E 0  D011       1100           STO     TEMP6                           HWE09030
045F 0  C01E       1101           LD      =9600                           HWE09040
0460 0  900F       1102           S       TEMP6                           HWE09050
0461 0  A01D       1103           M       =19650                          HWE09060
0462 0  1082       1104           SLT     2                               HWE09070
0463 0  D23D       1105           STO   2 VT188                           HWE09080
                   1106   *                      SELECT LOW               HWE09090
0464 0  C01B       1107           LD      =27687                          HWE09100
0465 0  A21E       1108           M     2 VT157                           HWE09110
0466 0  B23D       1109           CMP   2 VT188                           HWE09120
0467 0  C23D       1110           LD    2 VT188                           HWE09130
0468 0  1000       1111           NOP                                     HWE09140
0469 0  D23E       1112           STO   2 VT189                           HWE09150
                   1113   *                      SELECT HIGH              HWE09160
046A 0  B23F       1114           CMP   2 VT190                           HWE09170
046B 0  7002       1115           MDX     *+2                             HWE09180
046C 0  1000       1116           NOP                                     HWE09190
046D 0  C23F       1117           LD    2 VT190                           HWE09200
046E 0  D240       1118           STO   2 VT191  MINIMUM RATIOS           HWE09210
                   1119   *                      BRANCH TO VALVE CONTROL  HWE09220
046F 0  7011       1120           B       CNTLB                           HWE09230
0470 0  0000       1121   TEMP6   DC      *-*                             HWE09240
                   1122           LORG                                    HWE09250
0471 0  3F00       1123   +       DC      16128
0472 0  60E0       1124   +       DC      24800
0473 0  33B2       1125   +       DC      13234
0474 0  06E9       1126   +       DC      1769
0475 0  474A       1127   +       DC      18250
0476 0  0917       1128   +       DC      2327
0477 0  F3F8       1129   +       DC      -3080
0478 0  4074       1130   +       DC      16500
0479 0  0F25       1131   +       DC      3877
047A 0  0318       1132   +       DC      792
047B 0  4362       1133   +       DC      17250
```

Table B-13. Bendix Bounds Program (Continued)


```
047C 0  1B76     +        DC       7030
047D 0  1BBC     +        DC       7100
047E 0  2580     +        DC       9600
047F 0  4CC2     +        DC       19650
0480 0  6C27     +        DC       27687
0481              CNTLB   EQU      *              ADD VALVE CONTROL HERE      HWE09260
0481 0  C235              LD     2 VT180          THIS WILL BE COMPUTED VALU  HWE09270
0482 0  D235              STO    2 VT180          FROM ADDED CONTROL LOOP     HWE09280
0483 0  7000              B        VALPO                                      HWE09290
0484              VALPO   EQU      *                                          HWE09300
0484 0  C2E6              LD     2 VT026                                      HWE09310
0485 0  A236              M      2 VT181                                      HWE09320
0486 0  1082              SLT      2
0487 0  D237              STO    2 VT182                                      HWE09340
0488 0  C2E1              LD     2 VT031                                      HWE09350
0489 0  1885              SRT      5                                          HWE09360
048A 0  804A              A        =5320                                      HWE09370
048B 0  A268              M      2 VT231                                      HWE09380
048C 0  1083              SLT      3                                          HWE09390
048D 0  D243              STO    2 VT194                                      HWE09400
048E 0  C2E0              LD     2 VT032                                      HWE09410
048F 0  1080              SRT      0                                          HWE09420
0490 0  D20F              STO    2 VT142                                      HWE09430
0491 0  C20F              LD     2 VT033                                      HWE09440
0492 0  1083              SRT      3                                          HWE09450
0493 0  D210              STO    2 VT143                                      HWE09460
                 *                                VALVE ZERO FLOW TRIM        HWE09470
0494 0  C2F5              LD     2 VT011                                      HWE09480
0495 0  1886              SRT      6                                          HWE09490
0496 0  D20E              STO    2 VT141                                      HWE09500
0497 0  803E              A        =5400                                      HWE09510
0498 0  D214              STO    2 VT147                                      HWE09520
                 *                                MINIMUM VALVE               HWE09530
0499 0  C2E5              LD     2 VT027
049A 0  A240              M      2 VT191                                      HWE09550
049B 0  1081              SLT      1                                          HWE09560
049C 0  A243              M      2 VT194                                      HWE09570
049D 0  1084              SLT      4                                          HWE09580
049E 0  D241              STO    2 VT192                                      HWE09590
049F 0  B210              CMP    2 VT143                                      HWE09600
04A0 0  7002              MDX      *+2                                        HWE09610
04A1 0  1000              NOP                                                 HWE09620
04A2 0  C210              LD     2 VT143                                      HWE09630
04A3 0  D215              STO    2 VT148                                      HWE09640
04A4 0  C237              LD     2 VT182                                      HWE09650
04A5 0  B222              CMP    2 VT161          SELECT LOW WITH SPEED       HWE09660
04A6 0  C222              LD     2 VT161                                      HWE09670
04A7 0  1000              NOP                                                 HWE09680
                 *        SELECT HIGH                                         HWE09690
04A8 0  802E              CMP      =-4000                                     HWE09700
04A9 0  7002              MDX      *+2                                        HWE09710
04AA 0  1000              NOP                                                 HWE09720
04AB 0  C028              LD       =-4000                                     HWE09730
04AC 0  D238              STO    2 VT183                                      HWE09740
04AD 0  A243              M      2 VT194                                      HWE09750
04AE 0  1084              SLT      4                                          HWE09760
04AF 0  D239              STO    2 VT184                                      HWE09770
```

Table B-13. Bendix Bounds Program (Continued)


```
04B0 0  B20F      1191          CMP  2 VT142    SELECT LOW VALVE LIMIT     HWE09780
04B1 0  C20F      1192          LD   2 VT142                               HWE09790
04B2 0  1000      1193          NOP                                        HWE09800
04B3 0  D23A      1194          STO  2 VT185                               HWE09810
04B4 0  821F      1195          CMP  2 VT158    SELECT LOW WITH N SAFETY   HWE09820
04B5 0  C21F      1196          LD   2 VT158                               HWE09830
04B6 0  1000      1197          NOP                                        HWE09840
04B7 0  D23B      1198          STO  2 VT186                               HWE09850
04B8 0  B235      1199          CMP  2 VT180    SELECT LOW WITH CON LOOP   HWE09860
04B9 0  C235      1200          LD   2 VT180                               HWE09870
04BA 0  1000      1201          NOP                                        HWE09880
04BB 0  D23C      1202          STO  2 VT187                               HWE09890
04BC 0  B215      1203          CMP  2 VT148    SELECT HIGH WITH MINIMUM   HWE09900
04BD 0  7002      1204          MDX    *+2                                 HWE09910
04BE 0  1000      1205          NOP                                        HWE09920
04BF 0  C215      1206          LD   2 VT148                               HWE09930
04C0 0  D242      1207          STO  2 VT193                               HWE09940
04C1 0  8214      1208          A    2 VT147                               HWE09950
04C2 0  D244      1209          STO  2 VT195                               HWE09960
04C3 01 D4000585  1210          STO  L FUEL                                HWE09970
                  1211    *                                                HWE09980
                  1212    *                     IGV AND BLEED SCHEDULES    HWE09990
04C5 0  C276      1213          LD   2 VT245                               HWE10000
04C6 0  9011      1214          S      =13440                              HWE10010
04C7 0  A011      1215          M      =210                                HWE10020
04C8 0  1087      1216          SLT    7                                   HWE10030
04C9 0  8010      1217          A      =11800                              HWE10040
04CA 0  D251      1218          STO  2 VT208                               HWE10050
04CB 0  C276      1219          LD   2 VT245                               HWE10060
04CC 0  900E      1220          S      =17088                              HWE10070
04CD 01 4C2804DF  1221          BN     SAM6                                HWE10080
04CF 0  A00C      1222          M      =500                                HWE10090
04D0 0  1086      1223          SLT    6                                   HWE10100
04D1 0  800B      1224          A      =15800                              HWE10110
04D2 0  D253      1225          STO  2 VT210                               HWE10120
04D3 0  701C      1226          B      SAM8                                HWE10130
04D4 0  700A      1227          B      GOTO5                               HWE10140
                  1228          LORG                                       HWE10150
04D5 0  14C8      1229    +     DC     5320
04D6 0  1518      1230    +     DC     5400
04D7 0  F060      1231    +     DC     -4000
04D8 0  3480      1232    +     DC     13440
04D9 0  00D2      1233    +     DC     210
04DA 0  2E18      1234    +     DC     11800
04DB 0  42C0      1235    +     DC     17088
04DC 0  01F4      1236    +     DC     500
04DD 0  3DB8      1237    +     DC     15800
04DE 0  0000      1238  TEMPA   DC     *-*                                 HWE10160
04DF              1239  GOTO5   EQU    *                                   HWE10170
                  1240    *                                                HWE10180
04DF 0  C276      1241  SAM6    LD   2 VT245                               HWE10190
04E0 0  903A      1242          S      =15488                              HWE10200
04E1 01 4C2804EA  1243          BN     SAM7                                HWE10210
04E3 0  A038      1244          M      =128                                HWE10220
04E4 0  1086      1245          SLT    6                                   HWE10230
04E5 0  D0F8      1246          STO    TEMPA                               HWE10240
04E6 0  C036      1247          LD     =16000                              HWE10250
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Table B-13. Bendix Bounds Program (Continued)


```
04E7 0  90F6       1248          S         TEMPA                              HWE10260
04E8 0  D253       1249          STO     2 VT210                              HWE10270
04E9 0  7006       1250          B         SAM8                               HWE10280
                   1251    *                                                  HWE10290
04EA 0  C276       1252    SAM7  LD      2 VT245                              HWE10300
04EB 0  90EC       1253          S         =13440                             HWE10310
04EC 0  A031       1254          M         =1100                              HWE10320
04ED 0  1085       1255          SLT       5                                  HWE10330
04EE 0  8030       1256          A         =14900                             HWE10340
04EF 0  D253       1257          STO     2 VT210                              HWE10350
                   1258    *                                                  HWE10360
04F0 0  C2CD       1259    SAM8  LD      2 VT051                              HWE10370
04F1 0  1884       1260          SRT       4                                  HWE10380
04F2 0  D211       1261          STO     2 VT144                              HWE10390
04F3 0  C2CC       1262          LD      2 VT052                              HWE10400
04F4 0  1884       1263          SRT       4                                  HWE10410
04F5 0  8253       1264          A       2 VT210                              HWE10420
04F6 0  9211       1265          S       2 VT144                              HWE10430
04F7 0  9251       1266          S       2 VT208                              HWE10440
04F8 0  D255       1267          STO     2 VT212                              HWE10450
04F9 0  C21E       1268          LD      2 VT157                              HWE10460
04FA 0  9251       1269          S       2 VT208                              HWE10470
04FB 0  9211       1270          S       2 VT144                              HWE10480
                   1271    *  SELECT HIGH                                     HWE10490
04FC 0  8023       1272          CMP       =0                                 HWE10500
04FD 0  7002       1273          MDX       *+2                                HWE10510
04FE 0  1000       1274          NOP                                          HWE10520
04FF 0  C020       1275          LD        =0                                 HWE10530
0500 0  A020       1276          M         =8340                              HWE10540
0501 0  AA55       1277          D       2 VT212                              HWE10550
0502 0  801F       1278          A         =5100                              HWE10560
0503 0  D256       1279          STO     2 VT213                              HWE10570
0504 01 D4000586   1280          STO     L PIGV                               HWE10580
0506 0  C2CB       1281          LD      2 VT053                              HWE10590
0507 0  1884       1282          SRT       4                                  HWE10600
0508 0  D212       1283          STO     2 VT145                              HWE10610
0509 0  C2CA       1284          LD      2 VT054                              HWE10620
050A 0  1884       1285          SRT       4                                  HWE10630
050B 0  8253       1286          A       2 VT210                              HWE10640
050C 0  9212       1287          S       2 VT145                              HWE10650
050D 0  9251       1288          S       2 VT208                              HWE10660
050E 0  D257       1289          STO     2 VT214                              HWE10670
050F 0  C21E       1290          LD      2 VT157                              HWE10680
0510 0  9251       1291          S       2 VT208                              HWE10690
0511 0  9212       1292          S       2 VT145                              HWE10700
                   1293    *  SELECT HIGH                                     HWE10710
0512 0  800D       1294          CMP       =0                                 HWE10720
0513 0  7002       1295          MDX       *+2                                HWE10730
0514 0  1000       1296          NOP                                          HWE10740
0515 0  C00A       1297          LD        =0                                 HWE10750
0516 0  A00C       1298          M         =5050                              HWE10760
0517 0  AA57       1299          D       2 VT214                              HWE10770
0518 0  800B       1300          A         =3600                              HWE10780
0519 0  D258       1301          STO     2 VT215                              HWE10790
                   1302    *                                                  HWE10800
                   1303    *               STORE HERE IN BLEED IF SEPERATE CONTROHWE10810
                   1304    *               OF THE BLEEDS IS DESIRED           HWE10820
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Table B-13. Bendix Bounds Program (Continued)


```
                   1305   *               DAC 2 IS NOW USED FOR VTXXX OUTPUT   HWE10830
                   1306   *                                                    HWE10840
051A 0   700A      1307          B        GOTO6                                BEN10424
                   1308          LORG                                          BEN10425
051B 0   3C80      1309   +      DC       15488
051C 0   0080      1310   +      DC       128
051D 0   3E80      1311   +      DC       16000
051E 0   044C      1312   +      DC       1100
051F 0   3A34      1313   +      DC       14900
0520 0   0000      1314   +      DC       0
0521 0   2094      1315   +      DC       8340
0522 0   13EC      1316   +      DC       5100
0523 0   13BA      1317   +      DC       5050
0524 0   0E10      1318   +      DC       3600
0525               1319   GOTO6  EQU      *                                    BEN10426
                   1320   *                        NOZZLE CONTROL              HWE10850
0525 0   C049      1321          LD       =9250                                BEN10430
0526 0   921D      1322          S      2 VT156                                BEN10440
0527 0   A048      1323          M        =14320                               BEN10450
0528 0   1083      1324          SLT      3                                    BEN10460
0529 0   8047      1325          A        =13740                               BEN10470
                   1326   * SELECT LOW                                         BEN10480
052A 0   B047      1327          CMP      =12200                               BEN10490
052B 0   C046      1328          LD       =12200                               BEN10500
052C 0   1000      1329          NOP                                           BEN10510
052D 0   D25A      1330          STO    2 VT217                                BEN10570
052E 0   C044      1331          LD       =16042                               BEN10580
052F 0   921D      1332          S      2 VT156                                BEN10590
                   1333   * SELECT LOW                                         BEN10600
0530 0   B0EF      1334          CMP      =0                                   BEN10610
0531 0   C0EE      1335          LD       =0                                   BEN10620
0532 0   1000      1336          NOP                                           BEN10630
0533 0   A040      1337          M        =28900                               BEN10640
0534 0   1084      1338          SLT      4                                    BEN10650
0535 0   82C9      1339          A      2 VT055                                BEN10660
                   1340   * SELECT HIGH
0536 0   B25A      1341          CMP    2 VT217                                BEN10680
0537 0   7002      1342          MDX      *+2
0538 0   1000      1343          NOP
0539 0   C25A      1344          LD     2 VT217
053A 0   D25B      1345          STO    2 VT218                                BEN10710
                   1346   *                     TEMPERANCE CONTROL             BEN10720
053B 0   C279      1347          LD     2 VT240                                BEN10730
053C 0   92C8      1348          S      2 VT056                                BEN10740
                   1349   * SELECT HIGH                                        BEN10750
053D 0   B0E2      1350          CMP      =0                                   BEN10760
053E 0   7002      1351          MDX      *+2                                  BEN10770
053F 0   1000      1352          NOP                                           BEN10780
0540 0   C0DF      1353          LD       =0                                   BEN10790
0541 0   A2C7      1354          M      2 VT057                                BEN10800
0542 0   1084      1355          SLT      4                                    BEN10810
0543 0   825B      1356          A      2 VT218                                BEN10820
                   1357   * SELECT HIGH                                        BEN10830
0544 0   B25B      1358          CMP    2 VT218                                BEN10840
0545 0   7002      1359          MDX      *+2                                  BEN10850
0546 0   1000      1360          NOP                                           BEN10860
0547 0   C25B      1361          LD     2 VT218                                BEN10870
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Table B-13. Bendix Bounds Program (Continued)

```
0548 0  D25C                     STO   2 VT219                                 BEN10880
0549 0  D03E                     STO     NOZ                                   BEN10890
054A 0  C2E4                     LD    2 VT028     THIS GOES IN THE BOUNDS
054B 01 940002FB                 S     L =64       PROGRAM AT ADDRESS DONE
054D 01 4C200551                 BNZ     DONE      IF VT028=64 HW NOZ IS IN
054F 0  C2AF                     LD    2 VT081     IF VT028 NOT 64 BENDX IN
0550 0  D037                     STO     NOZ
0551                     DONE    EQU     *                                     HWE11220
                         *                                                     HWE11230
                         *                                                     HWE11240
0551 30 040565C0                 CALL    DAOP                                  HWE11250
0553 1  057A                     DC      DALST                                 HWE11260
                         *                                                     HWE11270
                         *                         FOLLOWS BEN11070            HWE11280
                         *                        LOOP DETERMINATION           HWE11290
0554 0  C242                     LD    2 VT193                                 HWE11300
0555 0  901F                     S       =20                                   HWE11310
0556 0  9215                     S     2 VT148                                 HWE11320
0557 01 4C280561                 BN      NEGA                                  HWE11330
0559 0  C242                     LD    2 VT193                                 HWE11340
055A 0  801A                     A       =20                                   HWE11350
055B 0  9239                     S     2 VT144                                 HWE11360
055C 01 4C300564                 BP      POSA                                  HWE11370
055E 0  C286                     LD    2 VT074                                 HWE11380
055F 0  D263                     STO   2 VT226                                 HWE11390
0560 0  7005                     B       CON1                                  HWE11400
0561 0  C014             NEGA    LD      =-32000   MIN CONTROL -5V OUT         HWE11410
0562 0  D263                     STO   2 VT226                                 HWE11420
0563 0  7002                     B       CON1                                  HWE11430
0564 0  C012             POSA    LD      =32000    MAX CONTROL  5V OUT         HWE11440
0565 0  D263                     STO   2 VT226                                 HWE11450
0566                     CON1    EQU     *                                     HWE11460
                         *                                                     HWE11470
0566 0  0811                     XIO     CEOFF                                 HWE11480
0567 00 65000000         XR1     LDX   L1 *-*                                  HWE11490
0569 00 66000000         XR2     LDX   L2 *-*                                  HWE11500
056B 00 67000000         XR3     LDX   L3 *-*                                  HWE11510
056D 01 4C800000                 BSC   I GTECT                                 HWE11520
                                 LORG                                          HWE11530
056F 0  2422             +       DC      9250
0570 0  37F0             +       DC      14320
0571 0  35AC             +       DC      13740
0572 0  2FA8             +       DC      12200
0573 0  3EAA             +       DC      16042
0574 0  70E4             +       DC      28900
0575 0  0014             +       DC      20
0576 0  8300             +       DC      -32000
0577 0  7D00             +       DC      32000
0578    0000             CEOFF   BSS   E 0                                     HWE11540
0578 0  0000                     DC      0                                     HWE11550
0579 0  E400                     DC      /E400                                 HWE11560
                         *                                                     HWE11570
057A 0  0000             DALST   DC      0                                     HWE11580
057B 0  0000                     DC      0
057C    0004                     BSS     4                                     HWE11600
0580 0  0000                     DC      *-*                                   HWE11610
0581 0  3000                     DC      /3000
0582 1  0583                     DC      AOLST                                 HWE11630
0583 0  0006             AOLST   DC      /0000+6
0584 0  0000             APZ     DC      0
0585 0  0000             FUEL    DC      *-*
0586 0  0000             PIGV    DC      *-*
0587 0  0000             BLEED   DC      *-*
0588 0  0000             NOZ     DC      *-*
0589 0  0000             ALOG4   DC      *-*
                         *                                                     HWE11750
                         *                                                     HWE11760
                         *                                                     HWE11770
```

Table B-13. Bendix Bounds Program (Continued)

0000	1431	P00	EQU	00	HWE11820
0001	1432	P01	EQU	01	HWE11830
0002	1433	P02	EQU	02	HWE11840
0003	1434	P03	EQU	03	HWE11850
0004	1435	P04	EQU	04	HWE11860
0005	1436	P05	EQU	05	HWE11870
0006	1437	P06	EQU	06	HWE11880
0007	1438	P07	EQU	07	HWE11890
0008	1439	P08	EQU	08	HWE11900
0009	1440	P09	EQU	09	HWE11910
000A	1441	P10	EQU	10	HWE11920
000B	1442	P11	EQU	11	HWE11930
000C	1443	P12	EQU	12	HWE11940
000D	1444	P13	EQU	13	HWE11950
000E	1445	P14	EQU	14	HWE11960
000F	1446	P15	EQU	15	HWE11970
0010	1447	P16	EQU	16	HWE11980
0011	1448	P17	EQU	17	HWE11990
0012	1449	P18	EQU	18	HWE12000
0013	1450	P19	EQU	19	HWE12010
0014	1451	P20	EQU	20	HWE12020
0015	1452	P21	EQU	21	HWE12030
0016	1453	P22	EQU	22	HWE12040
0017	1454	P23	EQU	23	HWE12050
0018	1455	P24	EQU	24	HWE12060
0019	1456	P25	EQU	25	HWE12070
001A	1457	P26	EQU	26	HWE12080
001B	1458	P27	EQU	27	HWE12090
001C	1459	P28	EQU	28	HWE12100
001D	1460	P29	EQU	29	HWE12110
001E	1461	P30	EQU	30	HWE12120
001F	1462	P31	EQU	31	HWE12130
0020	1463	P32	EQU	32	HWE12140
0021	1464	P33	EQU	33	HWE12150
0022	1465	P34	EQU	34	HWE12160
0023	1466	P35	EQU	35	HWE12170
0024	1467	P36	EQU	36	HWE12180
0025	1468	P37	EQU	37	HWE12190
0026	1469	P38	EQU	38	HWE12200
0027	1470	P39	EQU	39	HWE12210
0028	1471	P40	EQU	40	HWE12220
0029	1472	P41	EQU	41	HWE12230
002A	1473	P42	EQU	42	HWE12240
002B	1474	P43	EQU	43	HWE12250
002C	1475	P44	EQU	44	HWE12260
002D	1476	P45	EQU	45	HWE12270
002E	1477	P46	EQU	46	HWE12280
002F	1478	P47	EQU	47	HWE12290
0030	1479	P48	EQU	48	HWE12300
0031	1480	P49	EQU	49	HWE12310
0032	1481	P50	EQU	50	HWE12320
0033	1482	P51	EQU	51	HWE12330
0034	1483	P52	EQU	52	HWE12340
0035	1484	P53	EQU	53	HWE12350
0036	1485	P54	EQU	54	HWE12360
0037	1486	P55	EQU	55	HWE12370
0038	1487	P56	EQU	56	HWE12380
0039	1488	P57	EQU	57	HWE12390
003A	1489	P58	EQU	58	HWE12400
003B	1490	P59	EQU	59	HWE12410
003C	1491	P60	EQU	60	HWE12420
003D	1492	P61	EQU	61	HWE12430
003E	1493	P62	EQU	62	HWE12440
003F	1494	P63	EQU	63	HWE12450
	1495	*			HWE12460

Table B-13. Bendix Bounds Program (Continued)


```
                1497   *                           TRIM VALUES                  HWE12480
                1498   *                           STANDARD TRIMS XR1           HWE12490
                1499   *                              ANALOG TRIM EQU           HWE12500
                1500   *                                COMPUTED VALUES EQU     HWE12510
0001            1501   VT128 EQU      +1   SPEED REQUEST                        HWE12520
0002            1502   VT129 EQU      +2   SPEED REQUEST ERROR FOR INTEGRATHWE12530
0003            1503   VT130 EQU      +3   SPEED REQUEST INTEGRATION UP         HWE12540
0004            1504   VT131 EQU      +4   SPEED REQUEST INTEGRATION DOWN       HWE12550
0005            1505   VT132 EQU      +5   INTEGRATED SPEED REQUEST             HWE12560
0006            1506   VT133 EQU      +6   LIMIT UP                             HWE12570
0007            1507   VT134 EQU      +7   LIMIT DOWN                           HWE12580
0008            1508   VT135 EQU      +8   SCALED BASE RATIOS      FIG10-5      HWE12590
0009            1509   VT136 EQU      +9   SCALED START INTERCEPT FIG10-7       HWE12600
000A            1510   VT137 EQU      +10  SCALED THIRD RANGE      FIG10-7      HWE12610
000B            1511   VT138 EQU      +11  SCALED INC INTEGRATION FIG10-8       HWE12620
000C            1512   VT139 EQU      +12  SCALED DEC INTEGRATION FIG10-8       HWE12630
000D            1513   VT140 EQU      +13      SCALED MINIMUM RATIOS            HWE12640
000E            1514   VT141 EQU      +14      ZERO FLOW ADJUSTMENT             HWE12650
000F            1515   VT142 EQU      +15      MAXIMUM VALVE SETTING            HWE12660
0010            1516   VT143 EQU      +16      MINIMUM VALVE SETTING            HWE12670
0011            1517   VT144 EQU      +17  SCALED LOW N IGV        FIG10-12     HWE12680
0012            1518   VT145 EQU      +18  SCALED LOW N BLEEDS     FIG10-12     HWE12690
0013            1519   VT146 EQU      +19          TEMPERATURE REQ              HWE12700
0014            1520   VT147 EQU      +20  FUEL RATIOS FINAL       FIG10-8      HWE12710
0015            1521   VT148 EQU      +21  COMPUTED FUEL REQUEST   FIG10-8      HWE12720
0016            1522   VT149 EQU      +22  SELECTED VARIABLE STORAGE            HWE12730
                1523   *                   FIG10-3    RPM REQUEST CONTROL       HWE12740
0017            1524   VT150 EQU      +23             POWER LEVER RPM REQ       HWE12750
0018            1525   VT151 EQU      +24             LOW SPEED SET             HWE12760
0019            1526   VT152 EQU      +25             HIGH SPEED SET            HWE12770
001A            1527   VT153 EQU      +26             POS RPM DN/DT             HWE12780
001B            1528   VT154 EQU      +27             NEG RPM DN/DT             HWE12790
001C            1529   VT155 EQU      +28             SPEED LIMIT TEMP          HWE12800
001D            1530   VT156 EQU      +29             SPEED REQUEST             HWE12810
                1531   *                  FIG10-4     COMPUTED DIGITAL RPM      HWE12820
001E            1532   VT157 EQU      +30                                       HWE12830
001F            1533   VT158 EQU      +31             MAX FUEL REQUEST          HWE12840
0020            1534   VT159 EQU      +32             SPEED ERROR               HWE12850
0021            1535   VT160 EQU      +33             SPEED RATIOS ERROR        HWE12860
                1536   *                                                        HWE12870
                1537   *                   FIG10-5    PROPORTIONAL TEMP CON HWE12880
                1538   *                              VT146 TEMP REQ            HWE12890
0022            1539   VT161 EQU      +34      RATIOS SPEED CONTROL             HWE12900
0023            1540   VT162 EQU      +35             TEMP.RATIOS ERROR         HWE12910
0024            1541   VT163 EQU      +36             LOW OF RPM AND TEMP       HWE12920
                1542   *                   FIG10-5    PROP.PRESSURE CONTROL HWE12930
0025            1543   VT164 EQU      +37             PRESS REQUEST             HWE12940
0026            1544   VT165 EQU      +38             PRESS ERROR               HWE12950
0027            1545   VT166 EQU      +39             RATIOS PRESS ERROR        HWE12960
0028            1546   VT167 EQU      +40             LOW OF P,T,AND RPM        HWE12970
                1547   *                                                        HWE12980
0029            1548   VT168 EQU      +41             RESERVED =VT167           HWE12990
                1549   *                   FIG10-5    BASE RATIOS INTEGRATE HWE13000
002A            1550   VT169 EQU      +42             INTEGRATION VALUE         HWE13010
002B            1551   VT170 EQU      +43             BASE RATIOS INT PLUS      HWE13020
002C            1552   VT171 EQU      +44             RATIOS REQUEST            HWE13030
                1553   *                                                        HWE13040
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Table B-13. Bendix Bounds Program (Continued)


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               1554   *                    FIG10-7   MAX RATIOS SCHEDULE    HWE13050
0020           1555   VT172 EQU    +45               SCHEDULE T2 VALUE      HWE13060
002E           1556   VT173 EQU    +46               START RATIOS           HWE13070
002F           1557   VT174 EQU    +47               2ND RANGE START RATIO  HWE13080
0030           1558   VT175 EQU    +48               LOW OF 173 AND 174     HWE13090
0031           1559   VT176 EQU    +49               3RD RANGE VALUE        HWE13100
0032           1560   VT177 EQU    +50               HIGH OF 175 & 176      HWE13110
0033           1561   VT178 EQU    +51               ACC SCHEDULE           HWE13120
0034           1562   VT179 EQU    +52               LOW 178 & 177          HWE13130
0035           1563   VT180 EQU    +53          VALVE CONTROL INPUT POINT   HWE13140
0036           1564   VT181 EQU    +54          MAXIMUM RATIOS              HWE13150
0037           1565   VT182 EQU    +55          RATIOS MODIFIED             HWE13160
0038           1566   VT183 EQU    +56          LOW RATIOS WITH SPEED       HWE13170
0039           1567   VT184 EQU    +57          MAXIMUM VALVE DUE TO RATIO  HWE13180
               1568   *                    FIGURE 10A-3 AND 4 VALVE POS     HWE13190
003A           1569   VT185 EQU    +58          MAXIMUM VALVE               HWE13200
003B           1570   VT186 EQU    +59          MAX VALVE AFTER N SAFETY    HWE13210
003C           1571   VT187 EQU    +60          MAX VALVE AFTER OTHER CONT  HWE13220
003D           1572   VT188 EQU    +61          IDLE MINIMUM SCHEDULE       HWE13230
003E           1573   VT189 EQU    +62          IDLE MINIMUM RATIOS         HWE13240
003F           1574   VT190 EQU    +63          MINIMUM RATIOS              HWE13250
0040           1575   VT191 EQU    +64          MINIMUM RATIOS OUT          HWE13260
0041           1576   VT192 EQU    +65          MINIMUM VALVE REQUEST       HWE13270
0042           1577   VT193 EQU    +66          FUEL REQUEST                HWE13280
0043           1578   VT194 EQU    +67          FACTORED BURNER PRESSURE    HWE13290
0044           1579   VT195 EQU    +68          FUEL REQUEST OUTPUT         HWE13300
0045           1580   VT196 EQU    +69        FUEL RATIOS PROP. ADDER       HWE13310
               1581   *                                                     HWE13320
               1582   *                    FIG10-9  TEMPERATURE CONTROL     HWE13330
0046           1583   VT197 EQU    +70         TEMPERATURE REQUEST ACC      HWE13340
0047           1584   VT198 EQU    +71          TEMPERATURE ERROR ACC       HWE13350
0048           1585   VT199 EQU    +72          TEMPERATURE RATIO PROP ACC  HWE13360
0049           1586   VT200 EQU    +73          TEMPERATURE REQUEST DECEL   HWE13370
004A           1587   VT201 EQU    +74          TEMPERATURE ERROR DECEL     HWE13380
004B           1588   VT202 EQU    +75          TEMPERATURE RATIOS DECEL    HWE13390
               1589   *                                                     HWE13400
               1590   *                    FIG10-10  PRESSURE RATIO CONT    HWE13410
004C           1591   VT203 EQU    +76          DP/P LOW N SCHEDULE REQ     HWE13420
004D           1592   VT204 EQU    +77          DP/P MID N SCHEDULE REQ     HWE13430
004E           1593   VT205 EQU    +78          DP/P HIGH N SCHEDULE REQ    HWE13440
004F           1594   VT206 EQU    +79          DP/P ERROR                  HWE13450
0050           1595   VT207 EQU    +80          DP/P INTEGRATION            HWE13460
               1596   *                                                     HWE13470
               1597   *                    FIG10-12 IGV AND BLEED SCHEDULE  HWE13480
0051           1598   VT208 EQU    +81          LOW N SCHEDULE              HWE13490
0052           1599   VT209 EQU    +82                                      HWE13500
0053           1600   VT210 EQU    +83          HIGH N MID T                HWE13510
0054           1601   VT211 EQU    +84                                      HWE13520
0055           1602   VT212 EQU    +85          SPEED RANGE IGV             HWE13530
0056           1603   VT213 EQU    +86          IGV REQUEST DAC /           HWE13540
0057           1604   VT214 EQU    +87          SPEED RANGE BLEEDS          HWE13550
0058           1605   VT215 EQU    +88          BLEED REQUEST DAC2          HWE13560
               1606   *                                                     HWE13570
               1607   *                    FIG10-14  NOZZLE CONTROL         HWE13580
0059           1608   VT216 EQU    +89                                      HWE13590
005A           1609   VT217 EQU    +90          NOZZLE MID SPEED            HWE13600
005B           1610   VT218 EQU    +91          NOZZLE HIGH SPEED           HWE13610
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Table B-13. Bendix Bounds Program (Continued)


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005C   1611  VT219 EQU   +92      NOZZLE REQUEST DAC 3          HWE13620
005D   1612  VT220 EQU   +93      DAC4 OUTPUT VALUE             HWE13630
005E   1613  VT221 EQU   +94                                    HWE13640
005F   1614  VT222 EQU   +95                                    HWE13650
0060   1615  VT223 EQU   +96                                    HWE13660
0061   1616  VT224 EQU   +97      DAC2 OUTPUT ADJUSTMENT NO     HWE13670
0062   1617  VT225 EQU   +98      DAC2 OUTPUT VALUE             HWE13680
0063   1618  VT226 EQU   +99      EFFECTIVE LOOP OUTPUT         HWE13690
       1619  *                  ANALOG VARIABLE                 HWE13700
       1620  *                  FIRST STRIP                     HWE13710
0064   1621  VT227 EQU   +100           DP/P          EK14      HWE13720
0065   1622  VT228 EQU   +101           POWER LEVER   EK14      HWE13730
0066   1623  VT229 EQU   +102           INSTRUMENT VAR EK14T4   HWE13740
0067   1624  VT230 EQU   +103           BURNER PRESS    EK14    HWE13750
0068   1625  VT231 EQU   +104           BURNER PRESS    EK15P1  HWE13760
0069   1626  VT232 EQU   +105      DP= P3-PS          EK15P2    HWE13770
006A   1627  VT233 EQU   +106           P2 COMP INLET  EK15P3   HWE13780
006B   1628  VT234 EQU   +107           BLEED PRESS P23EK15P4   HWE13790
006C   1629  VT235 EQU   +108           POSITION INPUT EK15     HWE13800
006D   1630  VT236 EQU   +109           ANALOG SPEED INST       HWE13810
006E   1631  VT237 EQU   +110           BLEED PRESS P2.4    P5  HWE13820
006F   1632  VT238 EQU   +111           BLEED PRESS P2.5    P6  HWE13830
0070   1633  VT239 EQU   +112           TURBINE DISCH PRES P8   HWE13840
0071   1634  VT240 EQU   +113           ENGINE DISCH PRES P9    HWE13850
0072   1635  VT241 EQU   +114      PRESSURE RATIO               HWE13860
0073   1636  VT242 EQU   +115                                   HWE13870
0074   1637  VT243 EQU   +116                                   HWE13880
0075   1638  VT244 EQU   +117                                   HWE13890
       1639  *                  THIRD  STRIP             EK18   HWE13900
0076   1640  VT245 EQU   +118           COMP TEMP INLET     TA  HWE13910
0077   1641  VT246 EQU   +119           COMP TEMP DISCH     TB  HWE13920
0078   1642  VT247 EQU   +120           TURBINE INLET       TC  HWE13930
0079   1643  VT248 EQU   +121           TURBINE DISCH       TD  HWE13940
007A   1644  VT249 EQU   +122           POWER LEVER       PLA1  HWE13950
007B   1645  VT250 EQU   +123           POWER LEVER       PLA2  HWE13960
007C   1646  VT251 EQU   +124           FILTER-LEAD-LAG VAR     HWE13970
007D   1647  VT252 EQU   +125           SPARE                   HWE13980
007E   1648  VT253 EQU   +126           SPARE                   HWE13990
       1649  *                 SPARE POINT                      HWE14000
007F   1650  VT254 EQU   +127                                   HWE14010
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Table B-13. Bendix Bounds Program (Continued)


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             *                   TRIMS LOCATION VALVES        HWE14030
FFFF         VT001 EQU   -1                                   HWE14040
FFFE         VT002 EQU   -2                                   HWE14050
FFFD         VT003 EQU   -3                                   HWE14060
FFFC         VT004 EQU   -4                                   HWE14070
FFFB         VT005 EQU   -5                                   HWE14080
FFFA         VT006 EQU   -6                                   HWE14090
FFF9         VT007 EQU   -7                                   HWE14100
FFF8         VT008 EQU   -8                                   HWE14110
FFF7         VT009 EQU   -9                                   HWE14120
FFF6         VT010 EQU   -10                                  HWE14130
FFF5         VT011 EQU   -11                                  HWE14140
FFF4         VT012 EQU   -12                                  HWE14150
FFF3         VT013 EQU   -13                                  HWE14160
FFF2         VT014 EQU   -14                                  HWE14170
FFF1         VT015 EQU   -15                                  HWE14180
FFF0         VT016 EQU   -16                                  HWE14190
FFEF         VT017 EQU   -17                                  HWE14200
FFEE         VT018 EQU   -18                                  HWE14210
FFED         VT019 EQU   -19                                  HWE14220
FFEC         VT020 EQU   -20                                  HWE14230
FFEB         VT021 EQU   -21                                  HWE14240
FFEA         VT022 EQU   -22                                  HWE14250
FFE9         VT023 EQU   -23                                  HWE14260
FFE8         VT024 EQU   -24                                  HWE14270
FFE7         VT025 EQU   -25                                  HWE14280
FFE6         VT026 EQU   -26                                  HWE14290
FFE5         VT027 EQU   -27                                  HWE14300
FFE4         VT028 EQU   -28                                  HWE14310
FFE3         VT029 EQU   -29                                  HWE14320
FFE2         VT030 EQU   -30                                  HWE14330
FFE1         VT031 EQU   -31                                  HWE14340
FFE0         VT032 EQU   -32                                  HWE14350
FFDF         VT033 EQU   -33                                  HWE14360
FFDE         VT034 EQU   -34                                  HWE14370
FFDD         VT035 EQU   -35                                  HWE14380
FFDC         VT036 EQU   -36                                  HWE14390
FFDB         VT037 EQU   -37                                  HWE14400
FFDA         VT038 EQU   -38                                  HWE14410
FFD9         VT039 EQU   -39                                  HWE14420
FFD8         VT040 EQU   -40                                  HWE14430
FFD7         VT041 EQU   -41                                  HWE14440
FFD6         VT042 EQU   -42                                  HWE14450
FFD5         VT043 EQU   -43                                  HWE14460
FFD4         VT044 EQU   -44                                  HWE14470
FFD3         VT045 EQU   -45                                  HWE14480
FFD2         VT046 EQU   -46                                  HWE14490
FFD1         VT047 EQU   -47                                  HWE14500
FFD0         VT048 EQU   -48                                  HWE14510
FFCF         VT049 EQU   -49                                  HWE14520
FFCE         VT050 EQU   -50                                  HWE14530
FFCD         VT051 EQU   -51                                  HWE14540
FFCC         VT052 EQU   -52                                  HWE14550
FFCB         VT053 EQU   -53                                  HWE14560
FFCA         VT054 EQU   -54                                  HWE14570
FFC9         VT055 EQU   -55                                  HWE14580
FFC8         VT056 EQU   -56                                  HWE14590
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Table B-13. Bendix Bounds Program (Continued)

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FFC7	1709	VT057 EQU	-57		HWE14600
FFC6	1710	VT058 EQU	-58		HWE14610
FFC5	1711	VT059 EQU	-59		HWE14620
FFC4	1712	VT060 EQU	-60		HWE14630
FFC3	1713	VT061 EQU	-61		HWE14640
FFC2	1714	VT062 EQU	-62		HWE14650
FFC1	1715	VT063 EQU	-63		HWE14660
FFC0	1716	VT064 EQU	-64		HWE14670
FFBF	1717	VT065 EQU	-65		HWE14680
FFBE	1718	VT066 EQU	-66		HWE14690
FFBD	1719	VT067 EQU	-67		HWE14700
FFBC	1720	VT068 EQU	-68		HWE14710
FFBB	1721	VT069 EQU	-69		HWE14720
FFBA	1722	VT070 EQU	-70		HWE14730
FFB9	1723	VT071 EQU	-71		HWE14740
FFB8	1724	VT072 EQU	-72		HWE14750
FFB7	1725	VT073 EQU	-73		HWE14760
FFB6	1726	VT074 EQU	-74		HWE14770
FFB5	1727	VT075 EQU	-75		HWE14780
FFB4	1728	VT076 EQU	-76		HWE14790
FFB3	1729	VT077 EQU	-77		HWE14800
FFB2	1730	VT078 EQU	-78		HWE14810
FFB1	1731	VT079 EQU	-79		HWE14820
FFB0	1732	VT080 EQU	-80		HWE14830
FFAF	1733	VT081 EQU	-81		HWE14840
FFAE	1734	VT082 EQU	-82		HWE14850
FFAD	1735	VT083 EQU	-83		HWE14860
FFAC	1736	VT084 EQU	-84		HWE14870
FFAB	1737	VT085 EQU	-85		HWE14880
FFAA	1738	VT086 EQU	-86		HWE14890
FFA9	1739	VT087 EQU	-87		HWE14900
FFA8	1740	VT088 EQU	-88		HWE14910
FFA7	1741	VT089 EQU	-89		HWE14920
FFA6	1742	VT090 EQU	-90		HWE14930
FFA5	1743	VT091 EQU	-91		HWE14940
FFA4	1744	VT092 EQU	-92		HWE14950
FFA3	1745	VT093 EQU	-93		HWE14960
FFA2	1746	VT094 EQU	-94		HWE14970
FFA1	1747	VT095 EQU	-95	T2=10XF DEG	HWE14980
FFA0	1748	VT096 EQU	-96	T3=10XF DEG	HWE14990
FF9F	1749	VT097 EQU	-97	T4=10XF DEG	HWE15000
FF9E	1750	VT098 EQU	-98	T5=10XF DEG	HWE15010
FF9D	1751	VT099 EQU	-99	ADJUSTMENT NUMBER SELECTED	HWE15020
FF9C	1752	VT100 EQU	-100	ADJUSTMENT REGISTER NUMBER	HWE15030
FF9B	1753	VT101 EQU	-101	SAFETY DIGITAL NUMBER	HWE15040
FF9A	1754	VT102 EQU	-102	PB=100XPSI	HWE15050
FF99	1755	VT103 EQU	-103	DP=1000XPSI	HWE15060
FF98	1756	VT104 EQU	-104	P2=1000XPSI	HWE15070
FF97	1757	VT105 EQU	-105	P23-P2=100XPSI	HWE15080
FF96	1758	VT106 EQU	-106	P24-P2=100XPSI	HWE15090
FF95	1759	VT107 EQU	-107	P25-P2=100XPSI	HWE15100
FF94	1760	VT108 EQU	-108	P5 =100XPSI	HWE15110
FF93	1761	VT109 EQU	-109	P0 =1000XPSI	HWE15120
FF92	1762	VT110 EQU	-110		HWE15130
FF91	1763	VT111 EQU	-111		HWE15140
FF90	1764	VT112 EQU	-112		HWE15150
FF8F	1765	VT113 EQU	-113		HWE15160

Table B-13. Bendix Bounds Program (Concluded)


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FF8E          1766   VT114 EQU    -114                    HWE15170
FF8D          1767   VT115 EQU    -115                    HWE15180
FF8C          1768   VT116 EQU    -116                    HWE15190
FF8B          1769   VT117 EQU    -117                    HWE15200
FF8A          1770   VT118 EQU    -118                    HWE15210
FF89          1771   VT119 EQU    -119                    HWE15220
FF88          1772   VT120 EQU    -120                    HWE15230
FF87          1773   VT121 EQU    -121                    HWE15240
FF86          1774   VT122 EQU    -122                    HWE15250
FF85          1775   VT123 EQU    -123                    HWE15260
FF84          1776   VT124 EQU    -124                    HWE15270
FF83          1777   VT125 EQU    -125                    HWE15280
FF82          1778   VT126 EQU    -126                    HWE15290
FF81          1779   VT127 EQU    -127                    HWE15300
058A          1780         END                            HWE15310

000 ERROR(S) AND 000 WARNING(S) IN ABOVE ASSEMBLY.
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Table B-14. Bendix Bounds Program Cross Reference

SYMBOL	VALUE	REL	DEFN	REFERENCES-
PTH34	0789	1	964	959R
PTH41	0406	1	1018	1013R
PTH42	03FE	1	1012	1007R
PTH43	03F6	1	1006	1001R
PTH44	03EC	1	999	994R
PTH51	0446	1	1075	1070R
PTH52	043E	1	1069	1064R
PTH53	0436	1	1063	1058R
PTH54	042D	1	1056	1051R
POSA	0564	1	391	1384R
P00	0000	0	1431	
P01	0001	0	1432	
P02	0002	0	1433	
P03	0003	0	1434	
P04	0004	0	1435	
P05	0005	0	1436	
P06	0006	0	1437	
P07	0007	0	1438	
P08	0008	0	1439	
P09	0009	0	1440	
P10	000A	0	1441	
P11	000B	0	1442	
P12	000C	0	1443	
P13	000D	0	1444	
P14	000E	0	1445	
P15	000F	0	1446	
P16	0010	0	1447	
P17	0011	0	1448	
P18	0012	0	1449	506R
P19	0013	0	1450	508R
P20	0014	0	1451	510R
P21	0015	0	1452	512R
P22	0016	0	1453	514R
P23	0017	0	1454	516R
P24	0018	0	1455	518R
P25	0019	0	1456	520R
P26	001A	0	1457	522R
P27	001B	0	1458	525R
P28	001C	0	1459	527R
P29	001D	0	1460	529R
P30	001E	0	1461	531R
P31	001F	0	1462	533R
P32	0020	0	1463	535R
P33	0021	0	1464	537R
P34	0022	0	1465	539R
P35	0023	0	1466	541R
P36	0024	0	1467	547R
P37	0025	0	1468	549R
P38	0026	0	1469	551R
P39	0027	0	1470	553R
P40	0028	0	1471	555R
P41	0029	0	1472	560R
P42	002A	0	1473	565R
P43	002B	0	1474	570R
P44	002C	0	1475	574R
P45	002D	0	1476	577R
P46	002E	0	1477	579R
P47	002F	0	1478	583R
P48	0030	0	1479	587R

Table B-14. Bendix Bounds Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-		
P49	0031	0	1480	591R		
P50	0032	0	1481	596R		
P51	0033	0	1482	598R		
P52	0034	0	1483	600R		
P53	0035	0	1484	602R		
P54	0036	0	1485	605R		
P55	0037	0	1486	611P		
P56	0038	0	1487	617R		
P57	0039	0	1488	622R		
P58	003A	0	1489	627R		
P59	003B	0	1490	629R		
P60	003C	0	1491	631R		
P61	003D	0	1492	633R		
P62	003E	0	1493	635R		
P63	003F	0	1494	638R		
RAWN	01E3	1	483	461M	465R	
RDOUT	0165	1	360	355R		
RPM	01E0	1	479	455R		
RSTAL	0010	1	13	369R		
RSTSA	0175	1	378	373R		
SAFND	01C6	1	451	435R	443R	447R
SAM1	02C2	1	721	681M		
SAM2	02C3	1	722	720M		
SAM3	02E0	1	751	744M	746R	
SAM4	02E1	1	752	750M		
SAM6	04DF	1	1241	1221M		
SAM7	04EA	1	1252	1243M		
SAM8	04F0	1	1259	1226M	1250M	
START	0147	1	337	12R		
STTVT	00A9	1	188	74M		
ST000	004E	1	78	388R		
ST001	004F	1	79	14R		
ST002	0050	1	80	16R		
ST003	0051	1	81	18R		
ST004	0052	1	82	20R		
ST005	0053	1	83	22R		
ST006	0054	1	84	24R		
ST007	0055	1	85	26R		
ST008	0056	1	86	28R		
ST009	0057	1	89	30R		
ST010	0058	1	90	32R		
ST011	0059	1	91	34R		
ST012	005A	1	94	36R		
ST013	005B	1	95	38R		
ST014	005C	1	96	40R		
ST015	005D	1	97	42R		
ST016	005E	1	98	44R		
ST017	005F	1	99	46R		
ST018	0060	1	100	48R		
ST019	0061	1	101	50R		
ST020	0062	1	102	52R		
ST021	0063	1	103	54R		
ST022	0064	1	104	56R		
ST023	0065	1	105	58R		
ST024	0066	1	109	60R		
ST025	0067	1	110	62R		
ST026	0068	1	111	64R		
ST027	0069	1	114	66R		
ST028	006A	1	115	68R		

Table B-14. Bendix Bounds Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-
ST029	006B	1	116	70R
ST030	006C	1	[illegible]	72R
ST031	006D	1	118	189R
ST032	006E	1	119	191R
ST033	006F	1	120	193R
ST034	0070	1	121	195R
ST035	0071	1	122	197R
ST036	0072	1	126	199R
ST037	0073	1	127	201R
ST038	0074	1	128	203R
ST039	0075	1	129	205R
ST040	0076	1	130	207R
ST041	0077	1	131	209R
ST042	0078	1	132	211R
ST043	0079	1	133	213R
ST044	007A	1	134	215R
ST045	007B	1	135	217R
ST046	007C	1	136	219R
ST047	007D	1	137	221R
ST048	007E	1	138	223R
ST049	007F	1	139	225R
ST050	0080	1	140	[illegible]
ST051	0081	1	146	[illegible]
ST052	0082	1	147	231R
ST053	0083	1	148	233R
ST054	0084	1	149	235R
ST055	0085	1	152	237R
ST056	0086	1	153	239R
ST057	0087	1	154	241R
ST058	0088	1	155	243R
ST059	0089	1	156	245R
ST060	008A	1	157	247R
ST061	008B	1	158	249R
ST062	008C	1	159	251R
ST063	008D	1	160	253R
ST064	008E	1	161	255R
ST065	008F	1	162	257R
ST066	0090	1	163	259R
ST067	0091	1	164	261R
ST068	0092	1	165	263R
ST069	0093	1	166	265R
ST070	0094	1	167	267R
ST071	0095	1	168	269R
ST072	0096	1	169	271R
ST073	0097	1	170	273R
ST074	0098	1	171	275R
ST075	0099	1	172	277R
ST076	009A	1	173	279R
ST077	009B	1	174	281R
ST078	009C	1	175	283R
ST079	009D	1	176	285R
ST080	009E	1	177	287R
ST081	009F	1	178	289R
ST082	00A0	1	179	291R
ST083	00A1	1	180	293R
ST084	00A2	1	181	295R
ST085	00A3	1	182	297R
ST086	00A4	1	183	299R
ST087	00A5	1	184	301R

Table B-14. Bendix Bounds Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-										
ST088	00A6	1	185	303R										
ST089	00A7	1	186	305R										
ST090	00A8	1	187	307R										
TEMPA	04DE	1	1238	1246M	1248R									
TEMP2	01DD	1	474	477R										
TEMP3	0142	1	331	366M										
TEMP4	0143	1	332	354M	376R									
TEMP5	0144	1	333	387M	392M									
TEMP6	0470	1	1121	1100M	1102R									
TESTN	01E2	1	482	454M	457M									
TMNR	0140	1	329	346M	350M	351R	400R	416R						
TRIMS	0141	1	330	467M	544M									
T2100	03E1	1	990	806R										
T2125	0422	1	1047	804R										
T225	033E	1	849	812R										
T250	0381	1	909	810R										
T275	03B6	1	955	808R										
VALID	01CF	1	459	456M										
VALPO	0484	1	1143	1142M										
VALUE	013E	1	327	324R	353M	357R	359M							
VLVEC	01B8	1	440	431R										
VT001	FFFF	0	1653	15M	657R									
VT002	FFFE	0	1654	17M	661R									
VT003	FFFD	0	1655	19M	762R									
VT004	FFFC	0	1656	21M	679R									
VT005	FFFB	0	1657	23M	682R									
VT006	FFFA	0	1658	25M	685R									
VT007	FFF9	0	1659	27M	694R									
VT008	FFF8	0	1660	29M	697R									
VT009	FFF7	0	1661	31M	754R									
VT010	FFF6	0	1662	33M	765R									
VT011	FFF5	0	1663	35M	1161R									
VT012	FFF4	0	1664	37M										
VT013	FFF3	0	1665	39M										
VT014	FFF2	0	1666	41M										
VT015	FFF1	0	1667	43M										
VT016	FFF0	0	1668	45M										
VT017	FFEF	0	1669	47M										
VT018	FFEE	0	1670	49M										
VT019	FFED	0	1671	51M										
VT020	FFEC	0	1672	53M										
VT021	FFEB	0	1673	55M										
VT022	FFEA	0	1674	57M										
VT023	FFE9	0	1675	59M										
VT024	FFE8	0	1676	61M	843R	846R	878R	881R	938R	941R	984R	987R	1019R	1022R	1076R
				1079R										
VT025	FFE7	0	1677	63M	814R	849R	909R	955R	990R	1047R				
VT026	FFE6	0	1678	65M	1144R									
VT027	FFE5	0	1679	67M	1167R									
VT028	FFE4	0	1680	69M	1364R									
VT029	FFE3	0	1681	71M	1089R									
VT030	FFE2	0	1682	73M	1084R									
VT031	FFE1	0	1683	190M	1148R									
VT032	FFE0	0	1684	192M	1154R									
VT033	FFDF	0	1685	194M	1157R									
VT034	FFDE	0	1686	196M										
VT035	FFDD	0	1687	198M										
VT036	FFDC	0	1638	200M										
VT037	FFDB	0	1689	202M										

Table B-14. Bendix Bounds Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-	
VT038	FFDA	0	1690	204M	
VT039	FFD9	0	1691	206M	
VT040	FFD8	0	1692	208M	
VT041	FFD7	0	1693	210M	
VT042	FFD6	0	1694	212M	
VT043	FFD5	0	1695	214M	
VT044	FFD4	0	1696	216M	
VT045	FFD3	0	1697	218M	
VT046	FFD2	0	1698	220M	
VT047	FFD1	0	1699	222M	
VT048	FFD0	0	1700	224M	
VT049	FFCF	0	1701	226M	
VT050	FFCE	0	1702	228M	
VT051	FFCD	0	1703	230M	1259R
VT052	FFCC	0	1704	232M	1262R
VT053	FFCB	0	1705	234M	1281R
VT054	FFCA	0	1706	236M	1284R
VT055	FFC9	0	1707	238M	1339R
VT056	FFC8	0	1708	240M	1348R
VT057	FFC7	0	1709	242M	1354R
VT058	FFC6	0	1710	244M	
VT059	FFC5	0	1711	246M	
VT060	FFC4	0	1712	248M	
VT061	FFC3	0	1713	250M	
VT062	FFC2	0	1714	252M	
VT063	FFC1	0	1715	254M	
VT064	FFC0	0	1716	256M	
VT065	FFBF	0	1717	258M	
VT066	FFBE	0	1718	260M	
VT067	FFBD	0	1719	262M	
VT068	FFBC	0	1720	264M	
VT069	FFBB	0	1721	266M	
VT070	FFBA	0	1722	268M	
VT071	FFB9	0	1723	270M	
VT072	FFB8	0	1724	272M	
VT073	FFB7	0	1725	274M	
VT074	FFB6	0	1726	276M	1385R
VT075	FFB5	0	1727	278M	
VT076	FFB4	0	1728	280M	
VT077	FFB3	0	1729	282M	
VT078	FFB2	0	1730	284M	
VT079	FFB1	0	1731	286M	
VT080	FFB0	0	1732	288M	
VT081	FFAF	0	1733	290M	1367R
VT082	FFAE	0	1734	292M	
VT093	FFAD	0	1735	294M	
VT084	FFAC	0	1736	296M	
VT085	FFAB	0	1737	298M	
VT086	FFAA	0	1738	300M	
VT087	FFA9	0	1739	302M	
VT088	FFA8	0	1740	304M	
VT089	FFA7	0	1741	306M	
VT090	FFA6	0	1742	308M	
VT091	FFA5	0	1743		
VT092	FFA4	0	1744		
VT093	FFA3	0	1745	462M	
VT094	FFA2	0	1746	342M	
VT095	FFA1	0	1747	610M	
VT096	FFA0	0	1748	616M	

Table B-14. Bendix Bounds Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-						
VT097	FF9F	0	1749	621M						
VT098	FF9E	0	1750	626M						
VT099	FF9D	0	1751	371R	375M					
VT100	FF9C	0	1752	377M						
VT101	FF9B	0	1753	367M	378R	397R	413R	429R	432R	444R
VT102	FF9A	0	1754	559M						
VT103	FF99	0	1755	564M						
VT104	FF98	0	1756	569M						
VT105	FF97	0	1757	573M						
VT106	FF96	0	1758	582M						
VT107	FF95	0	1759	586M						
VT108	FF94	0	1760	590M						
VT109	FF93	0	1761	595M						
VT110	FF92	0	1762	507M						
VT111	FF91	0	1763	509M						
VT112	FF90	0	1764	511M						
VT113	FF8F	0	1765	513M						
VT114	FF8E	0	1766	515M						
VT115	FF8D	0	1767	517M						
VT116	FF8C	0	1768	519M						
VT117	FF8B	0	1769	521M						
VT118	FF8A	0	1770	523M						
VT119	FF89	0	1771	526M						
VT120	FF88	0	1772	528M						
VT121	FF87	0	1773	530M						
VT122	FF86	0	1774	532M						
VT123	FF85	0	1775	534M						
VT124	FF84	0	1776	536M						
VT125	FF83	0	1777	538M						
VT126	FF82	0	1778	540M						
VT127	FF81	0	1779	542M						
VT128	0001	0	1501	678M	705R	721R				
VT129	0002	0	1502	707M						
VT130	0003	0	1503	712M						
VT131	0004	0	1504	718M						
VT132	0005	0	1505	706R	719R	722M	730R	731R		
VT133	0006	0	1506	684M	689R	692R				
VT134	0007	0	1507	696M	701R	702R				
VT135	0008	0	1508							
VT136	0009	0	1509							
VT137	000A	0	1510							
VT138	000B	0	1511							
VT139	000C	0	1512							
VT140	000D	0	1513	1086M	1091R					
VT141	000E	0	1514	1163M						
VT142	000F	0	1515	1156M	1191R	1192R				
VT143	0010	0	1516	1159M	1173R	1176R				
VT144	0011	0	1517	1261M	1265R	1270R				
VT145	0012	0	1518	1283M	1287R	1292R				
VT146	0013	0	1519							
VT147	0014	0	1520	1165M	1208R					
VT148	0015	0	1521	1177M	1203R	1206R	1379R			
VT149	0016	0	1522	401M	404R					
VT150	0017	0	1524	668M						
VT151	0018	0	1525	660M	670R	673R				
VT152	0019	0	1526	664M	675R	676R				
VT153	001A	0	1527	693M	709R	710R				
VT154	001B	0	1528	704M	714R	717R				
VT155	001C	0	1529	728M						

Table B-14. Bendix Bounds Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-											
VT156	001D	0	1530	733M	759R	1322R	1332R								
VT157	001E	0	1532	441R	466M	740R	760R	817R	824R	844R	852R	859R	879R	912R	919R
				939R	958R	965R	985R	993R	1000R	1020R	1050R	1057R	1077R	1087R	1095R
				1108R	1268R	1290R									
VT158	001F	0	1533	752M	1195R	1196R									
VT159	0020	0	1534	761M											
VT160	0021	0	1535	764M	767R										
VT161	0022	0	1539	768M	777M	1179R	1180R								
VT162	0023	0	1540												
VT163	0024	0	1541												
VT164	0025	0	1543												
VT165	0026	0	1544												
VT166	0027	0	1545												
VT167	0028	0	1546												
VT168	0029	0	1548												
VT169	002A	0	1550												
VT170	002B	0	1551												
VT171	002C	0	1552												
VT172	002D	0	1555												
VT173	002E	0	1556												
VT174	002F	0	1557												
VT175	0030	0	1558												
VT176	0031	0	1559												
VT177	0032	0	1560												
VT178	0033	0	1561												
VT179	0034	0	1562												
VT180	0035	0	1563	758M	1140R	1141M	1199R	1200R							
VT181	0036	0	1564	1082M	1145R										
VT182	0037	0	1565	1147M	1178R										
VT183	0038	0	1566	1187M											
VT184	0039	0	1567	1190M	1383R										
VT185	003A	0	1569	1194M											
VT186	003B	0	1570	1198M											
VT187	003C	0	1571	1202M											
VT188	003D	0	1572	1105M	1109R	1110R									
VT189	003E	0	1573	1112M											
VT190	003F	0	1574	1093M	1114R	1117R									
VT191	0040	0	1575	1118M	1168R										
VT192	0041	0	1576	1172M											
VT193	0042	0	1577	1207M	1377R	1381R									
VT194	0043	0	1578	1153M	1170R	1168R									
VT195	0044	0	1579	1209M											
VT196	0045	0	1580												
VT197	0046	0	1583												
VT198	0047	0	1584												
VT199	0048	0	1585												
VT200	0049	0	1586												
VT201	004A	0	1587												
VT202	004B	0	1588												
VT203	004C	0	1591												
VT204	004D	0	1592												
VT205	004E	0	1593												
VT206	004F	0	1594												
VT207	0050	0	1595												
VT208	0051	0	1598	1218M	1266R	1269R	1268R	1291R							
VT209	0052	0	1599												
VT210	0053	0	1600	1225M	1249R	1257M	1264R	1286R							
VT211	0054	0	1601												
VT212	0055	0	1602	1267M	1277R										

Table B-14. Bendix Bounds Program Cross Reference (Continued)

SYMBOL	VALUE	REL	DEFN	REFERENCES-						
VT213	0056	0	1603	1279M						
VT214	0057	0	1604	1289M	1299R					
VT215	0058	0	1605	1301M						
VT216	0059	0	1608							
VT217	005A	0	1609	1330M	1341R	1344R				
VT218	005B	0	1610	1345M	1356R	1358R	1361R			
VT219	005C	0	1611	1362M						
VT220	005D	0	1612	410M						
VT221	005E	0	1613							
VT222	005F	0	1614							
VT223	0060	0	1615							
VT224	0061	0	1616	417M	420R					
VT225	0062	0	1617	426M						
VT226	0063	0	1618	1386M	1389M	1392M				
VT227	0064	0	1621	548M						
VT228	0065	0	1622	550M						
VT229	0066	0	1623	552M						
VT230	0067	0	1624	554M						
VT231	0068	0	1625	556M	686R	698R	1151R			
VT232	0069	0	1626	561M						
VT233	006A	0	1627	566M	747R					
VT234	006B	0	1628	571M						
VT235	006C	0	1629	575M						
VT236	006D	0	1630	578M	737R	738R				
VT237	006E	0	1631	580M						
VT238	006F	0	1632	584M						
VT239	0070	0	1633	588M						
VT240	0071	0	1634	592M						
VT241	0072	0	1635	597M						
VT242	0073	0	1636	599M						
VT243	0074	0	1637	601M						
VT244	0075	0	1638	603M						
VT245	0076	0	1640	607M	723R	802R	1213R	1219R	1241R	1252R
VT246	0077	0	1641	613M						
VT247	0078	0	1642							
VT248	0079	0	1643	624M	1347R					
VT249	007A	0	1644	628M	6[illegible]5R					
VT250	007B	0	1645	630M						
VT251	007C	0	1646	632M						
VT252	007D	0	1647	634M						
VT253	007E	0	1648	636M						
VT254	007F	0	1650	639M						
WFP3	02F7	1	785	769M						
XR1	0567	1	1396	3M						
XR2	0569	1	1397	4M						
XR3	056F	1	1398	5M						

```
GTECT
DMP FUNCTION COMPLETED
*STORE              GTECT                                   HWE15320
GTECT
DMP FUNCTION COMPLETED
```

Table B-14. Bendix Bounds Program Cross Reference (Concluded)

```
// JOB          VDISK   17 JUL 74 16.083 HRS
// DMP    17 JUL 74 16.083 HRS
*DELETE    S            GTE85 *****
DMP FUNCTION COMPLETED
*STORECI  S             GTE85                       04

*INCLDGTEIN/0400,GTECT/0604,GETTM/0909
*CCEND


 MPX, BUILD GTE85

 R20  GTEIN LEV.0 NON-REENT PROG

 R20  GTECT LEV.0 NON-REENT PROG

 R20  GETTM LEV.0 NON-REENT PROG

 R20  HWECT LEV.0 NON-REENT PROG

 MPX, GTE85 LD XQ

CL WC OF  0080 STORED AT  04FE
DMP FUNCTION COMPLETED
// END   17 JUL 74 16.105 HRS
```

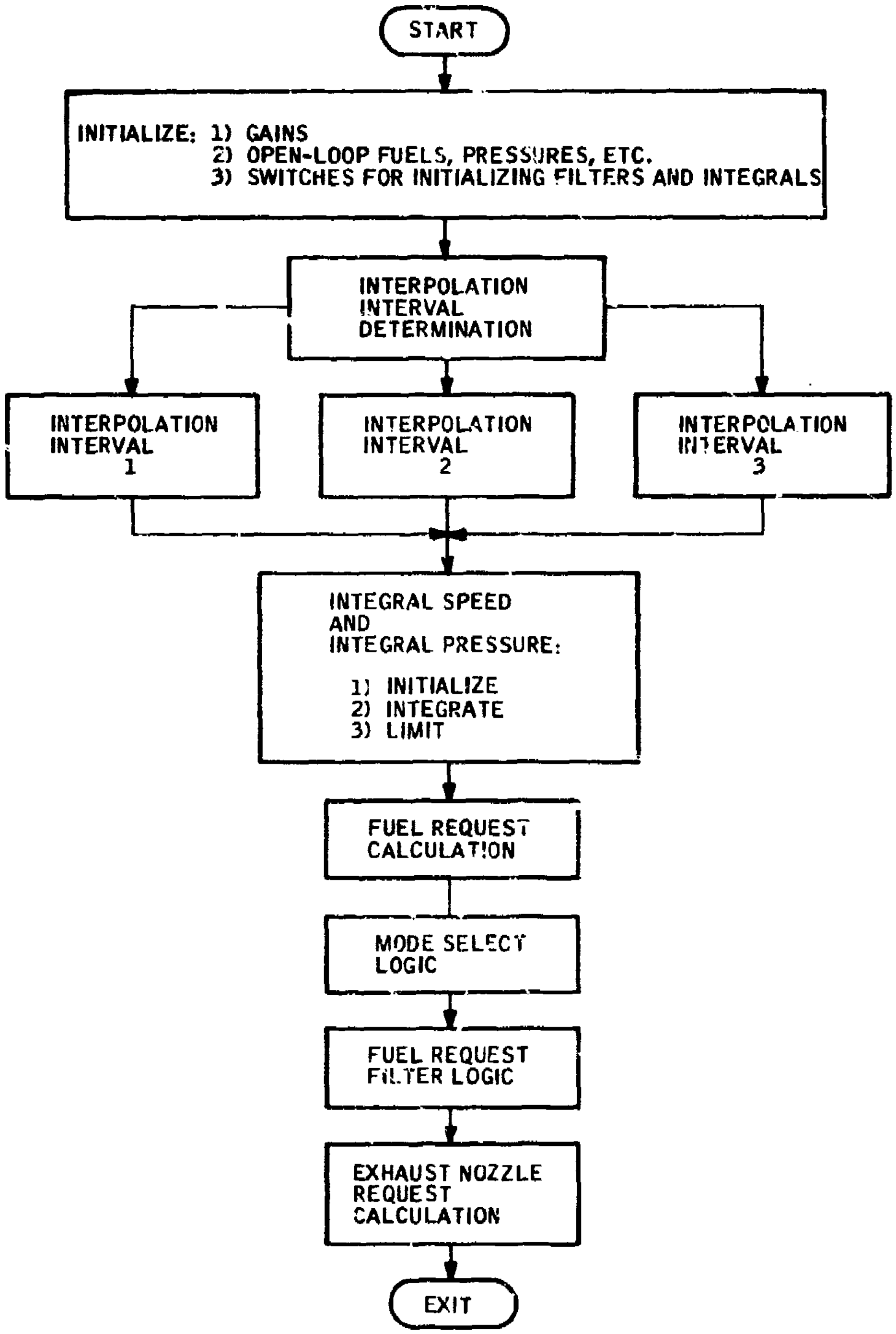

Figure B-1. Functional Flow Diagram Speed and Pressure Control Program

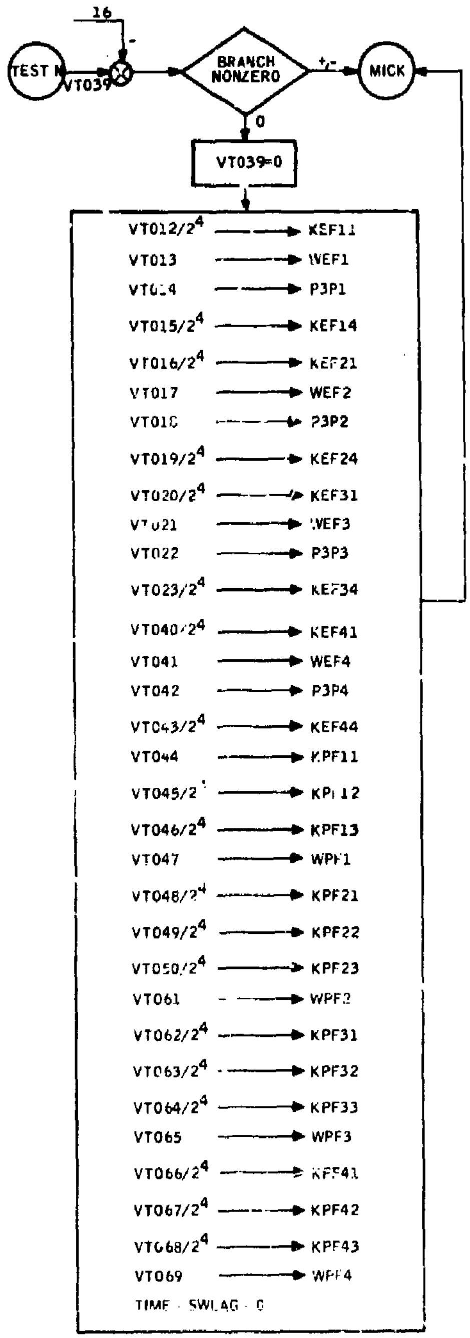

Figure B-2. Initialization Logic for Speed and Pressure Program

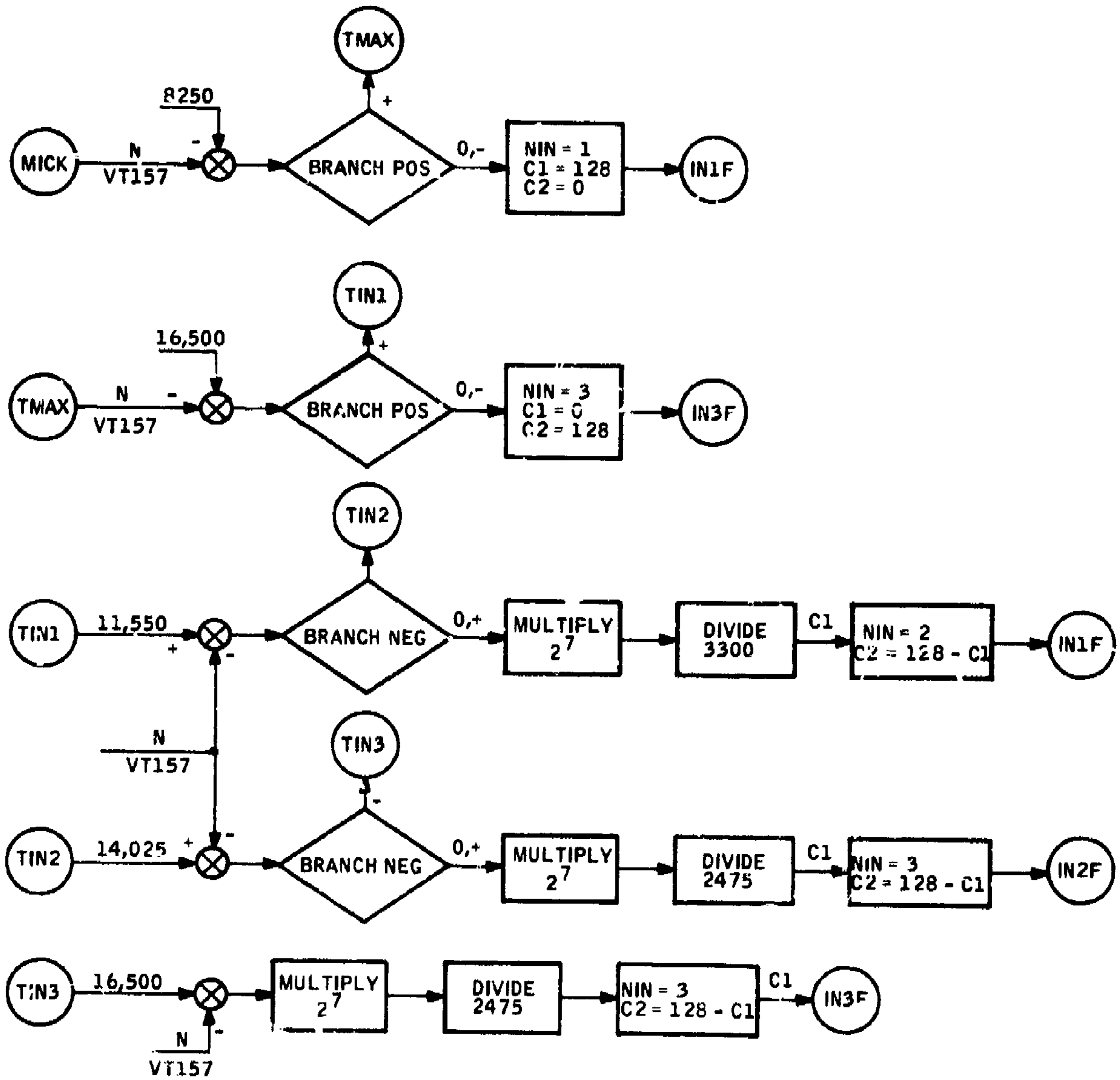

Figure B-3. Interval Determination

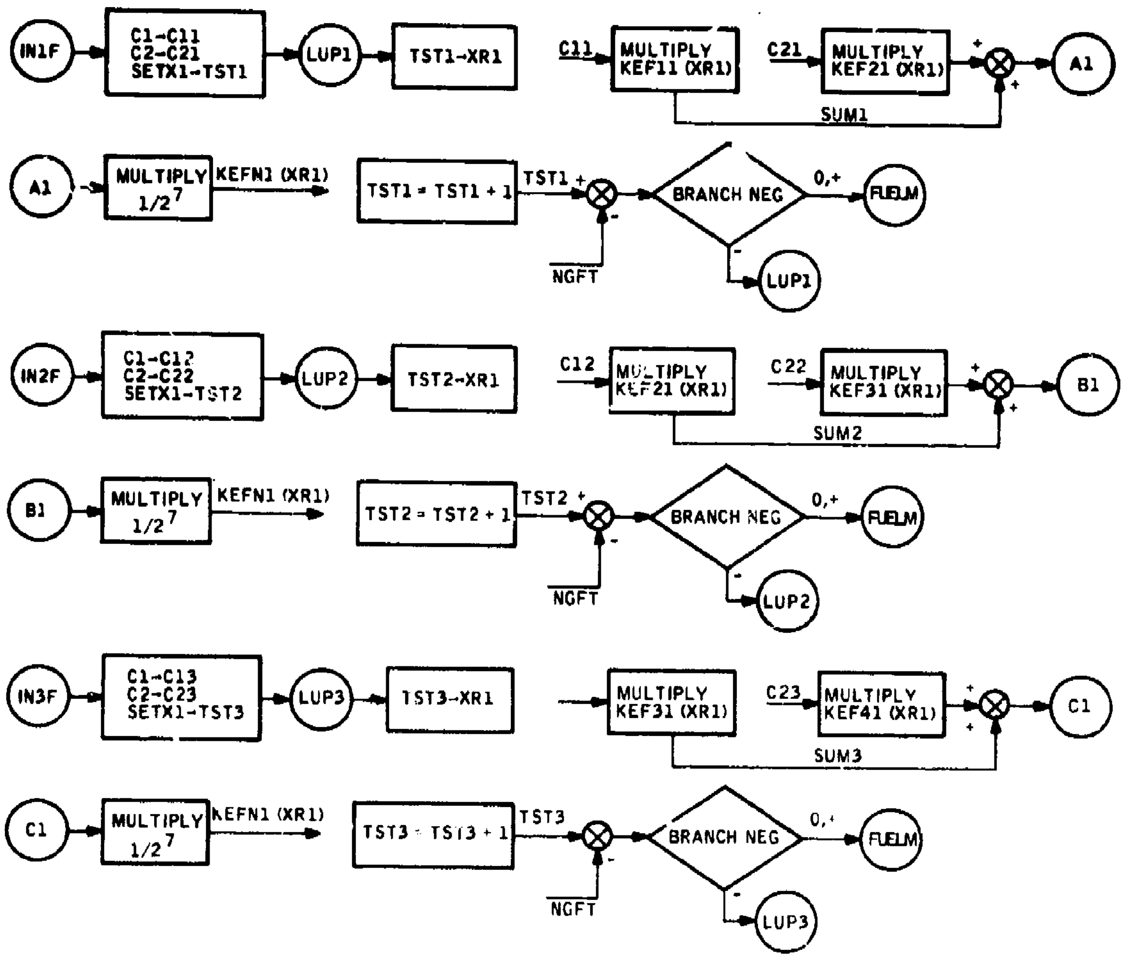

Figure B-4. Interpolation Logic

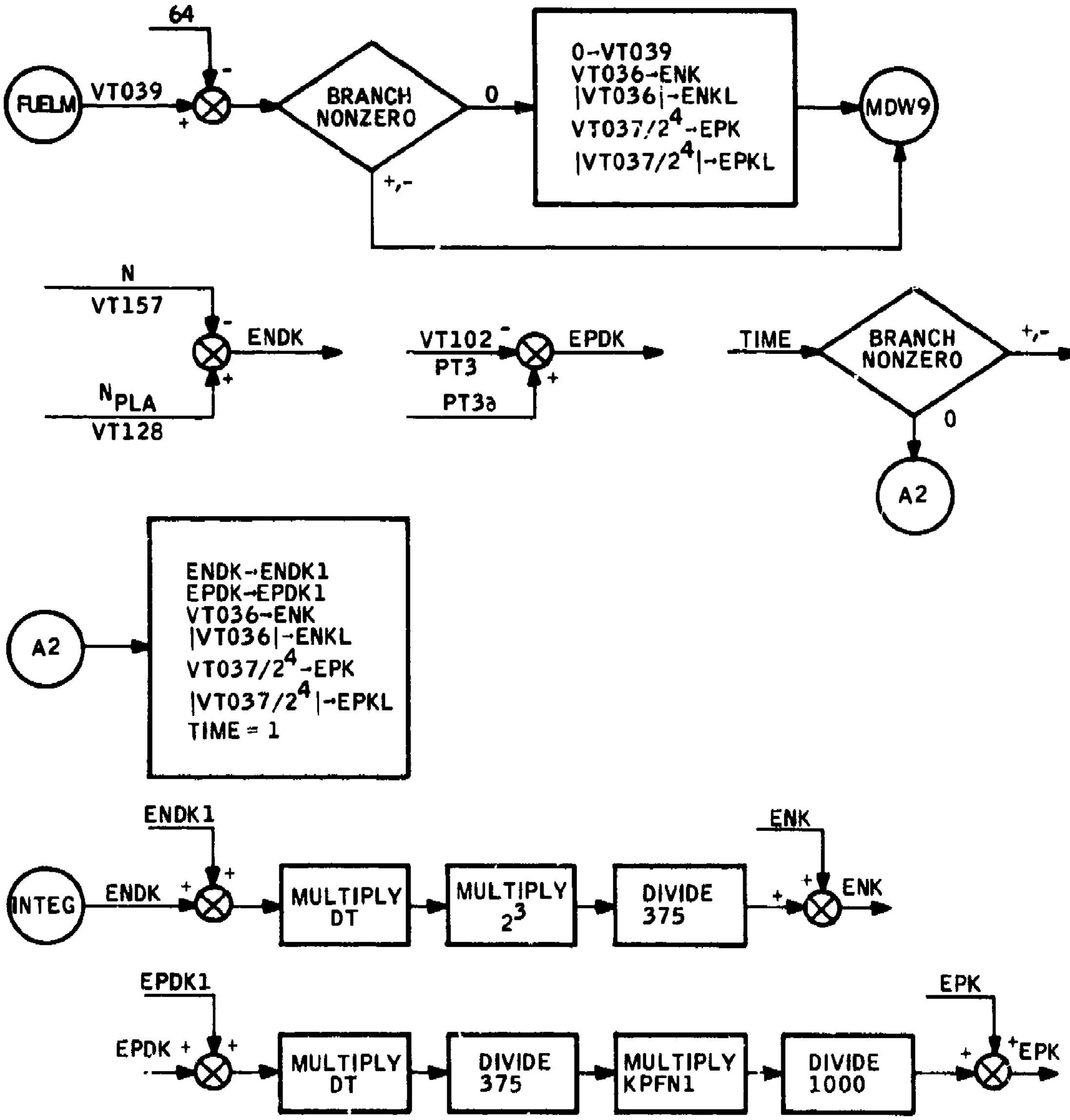

Figure B-5. Integral Speed and Pressure Calculation

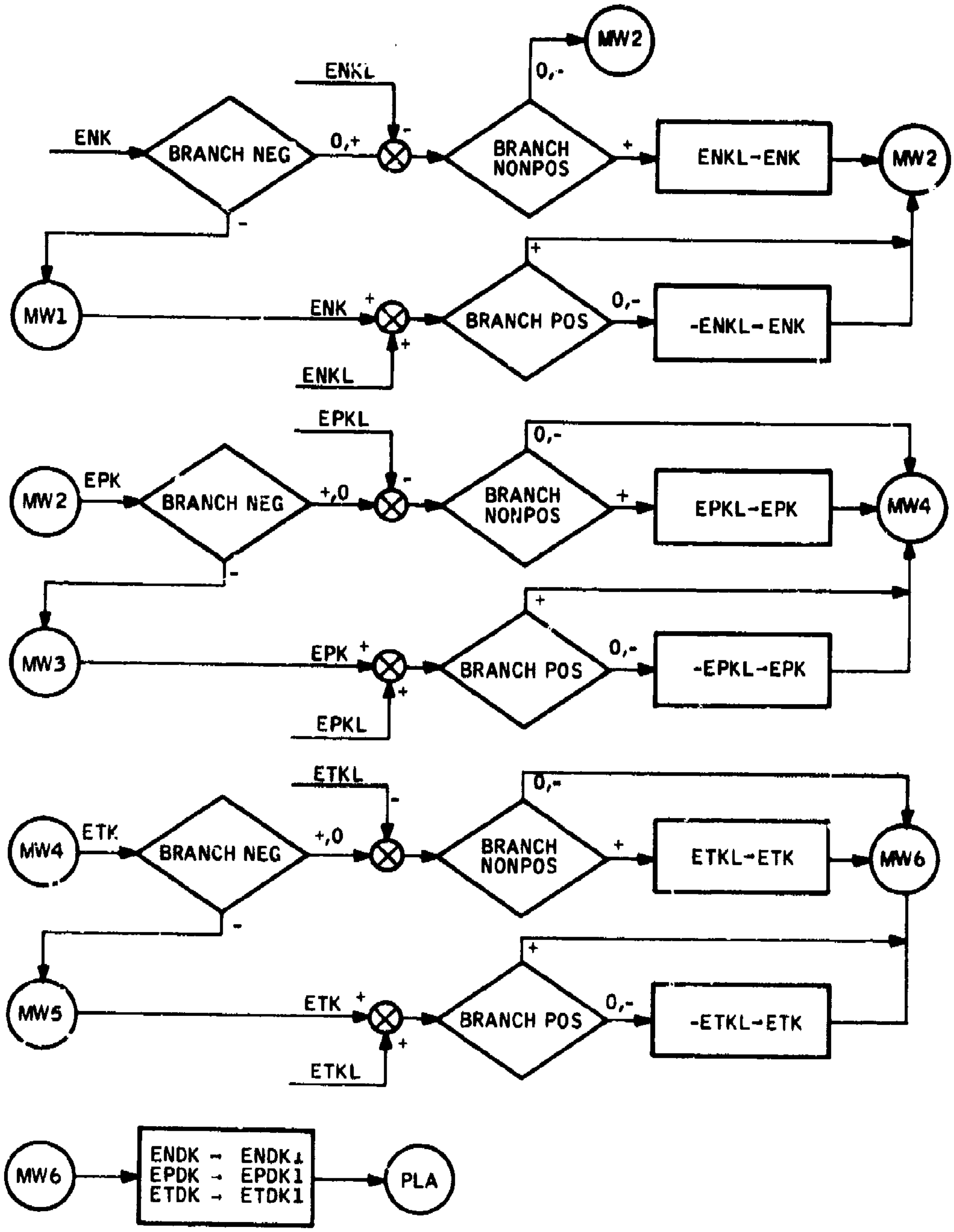

Figure B-6. Limiting Logic for Integral Speed and Pressure

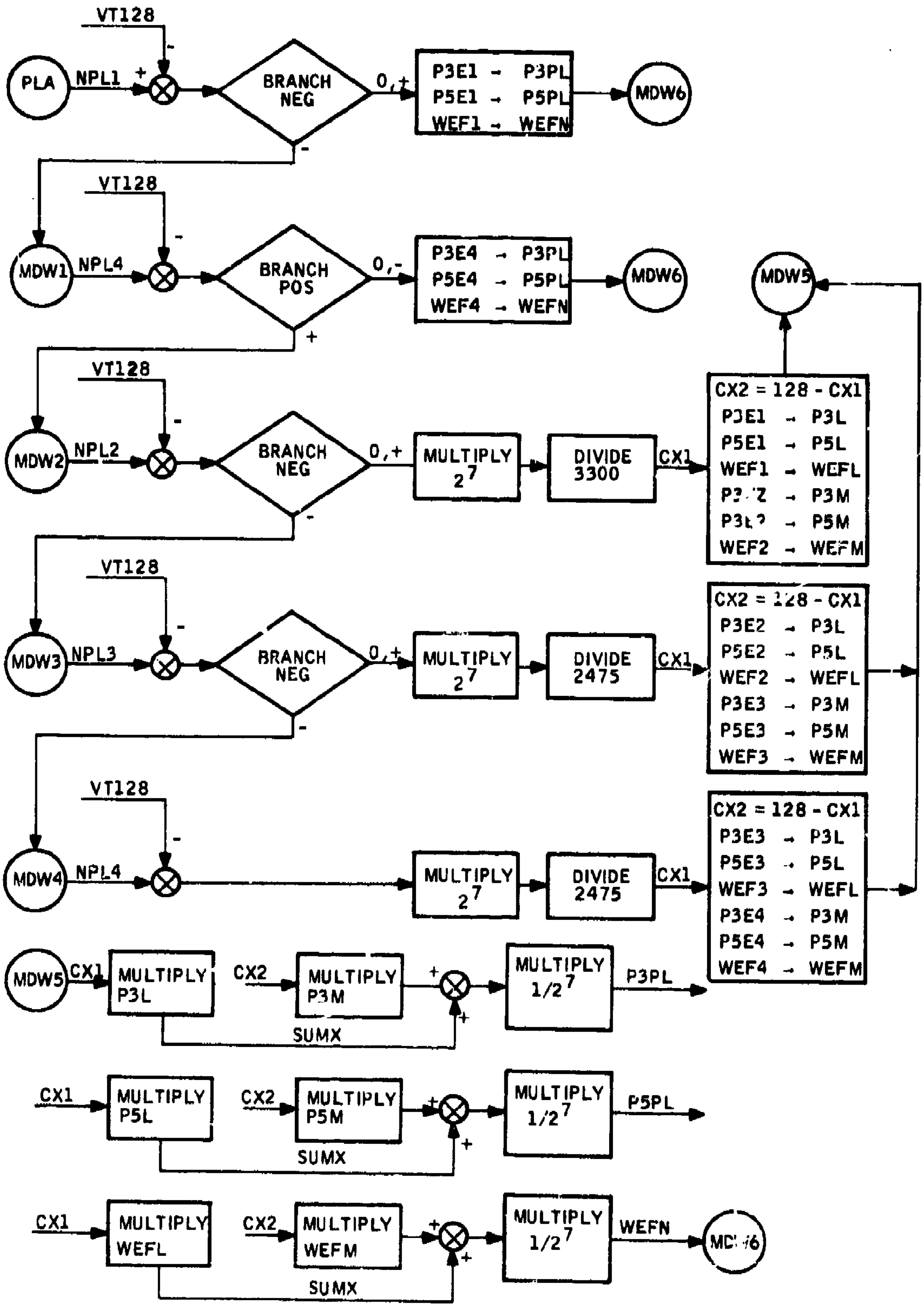

Figure B-7. Interpolation for PT3, PT5 and Fuel Request as a Function of Lower Lever

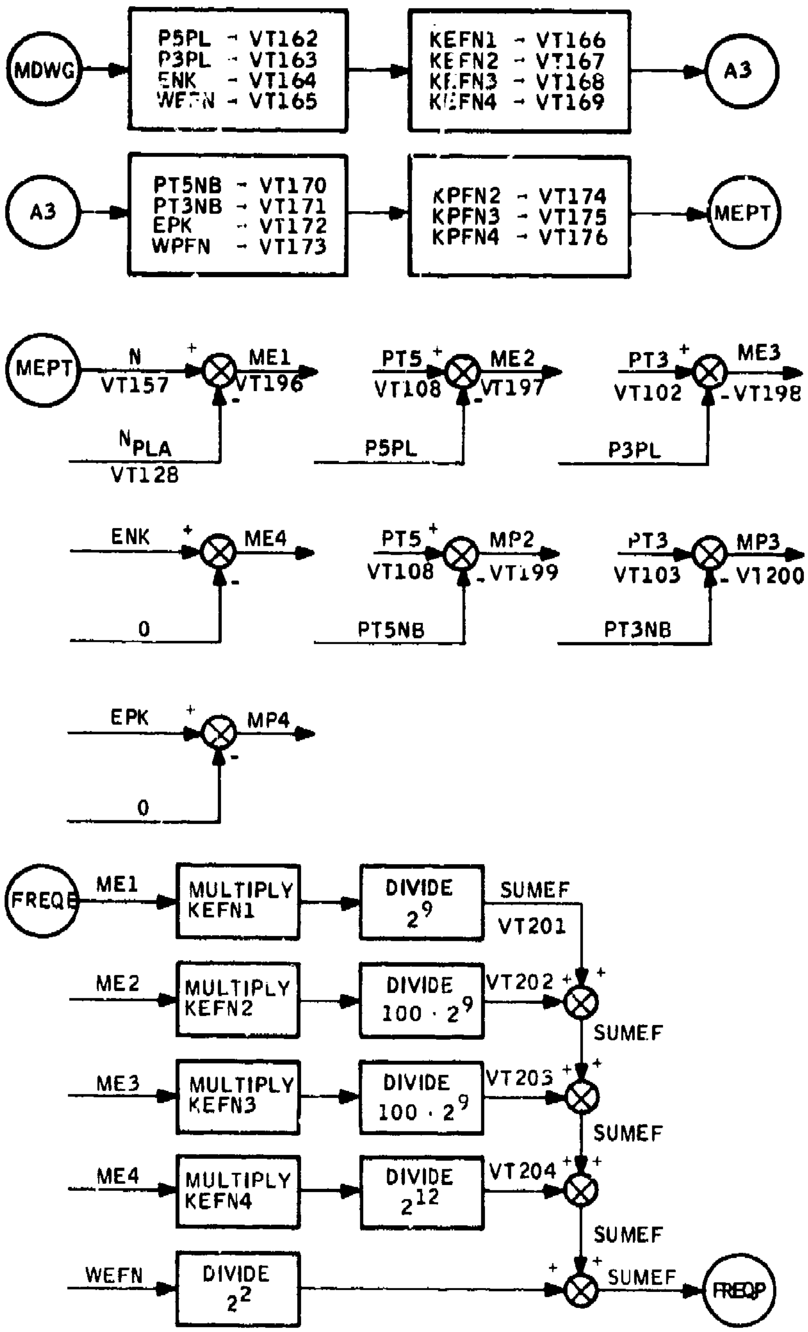

Figure B-8. Fuel Request Calculation

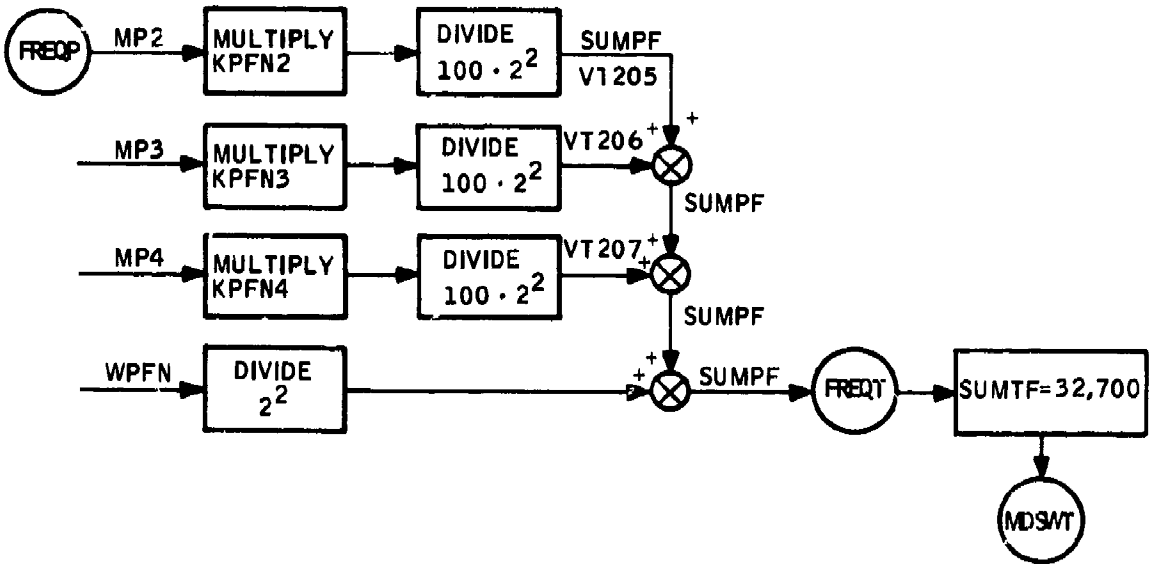

Figure B-8. Fuel Request Calculation (Concluded)

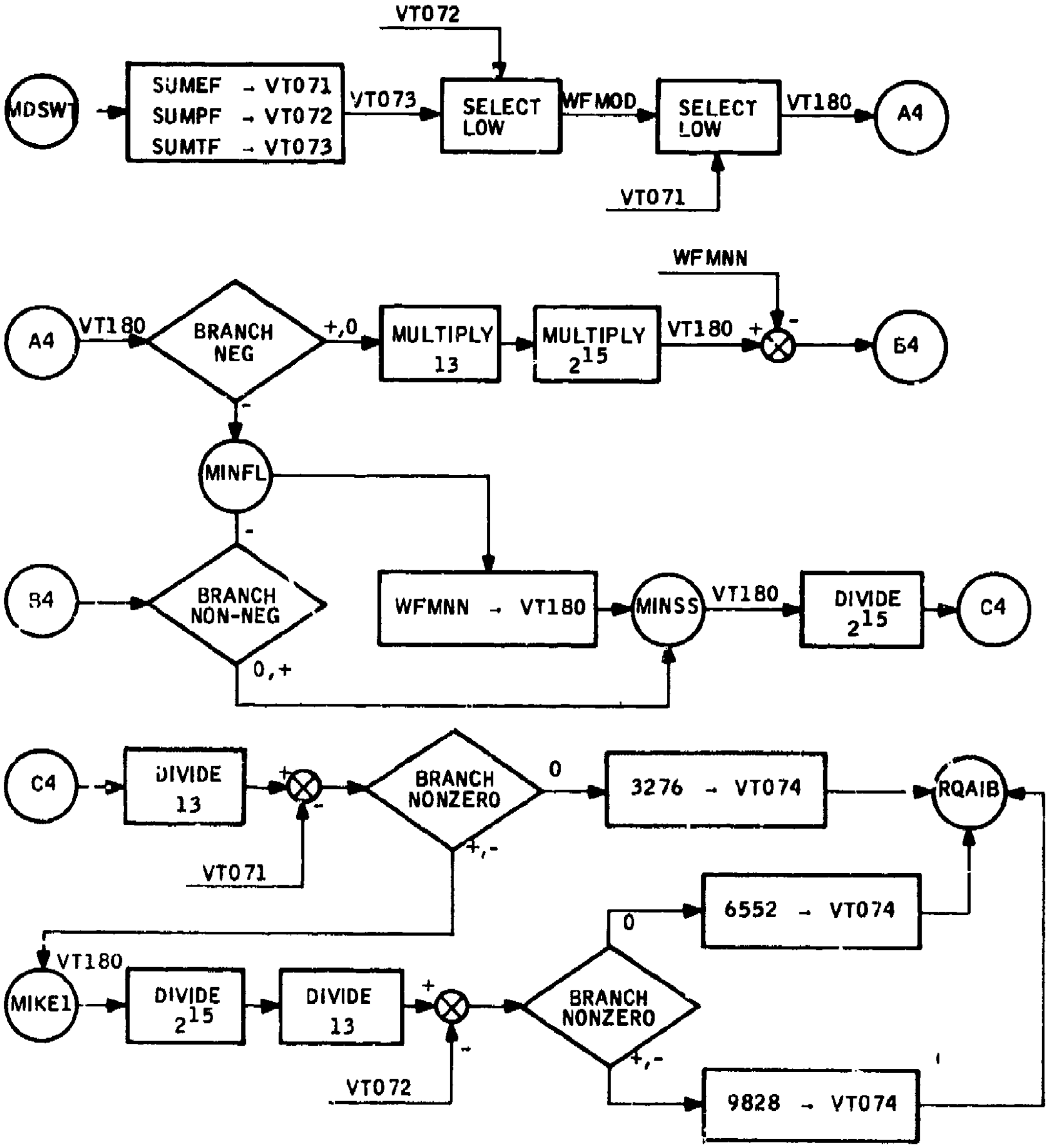

Figure B-9. Mode Select Logic

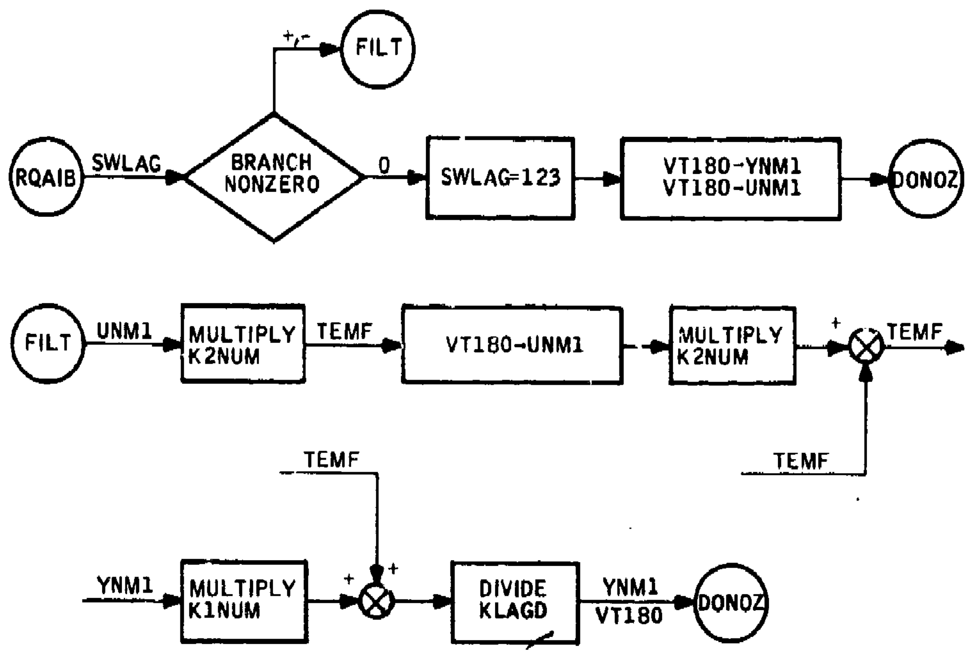

Figure B-10. Fuel Request Filter Logic

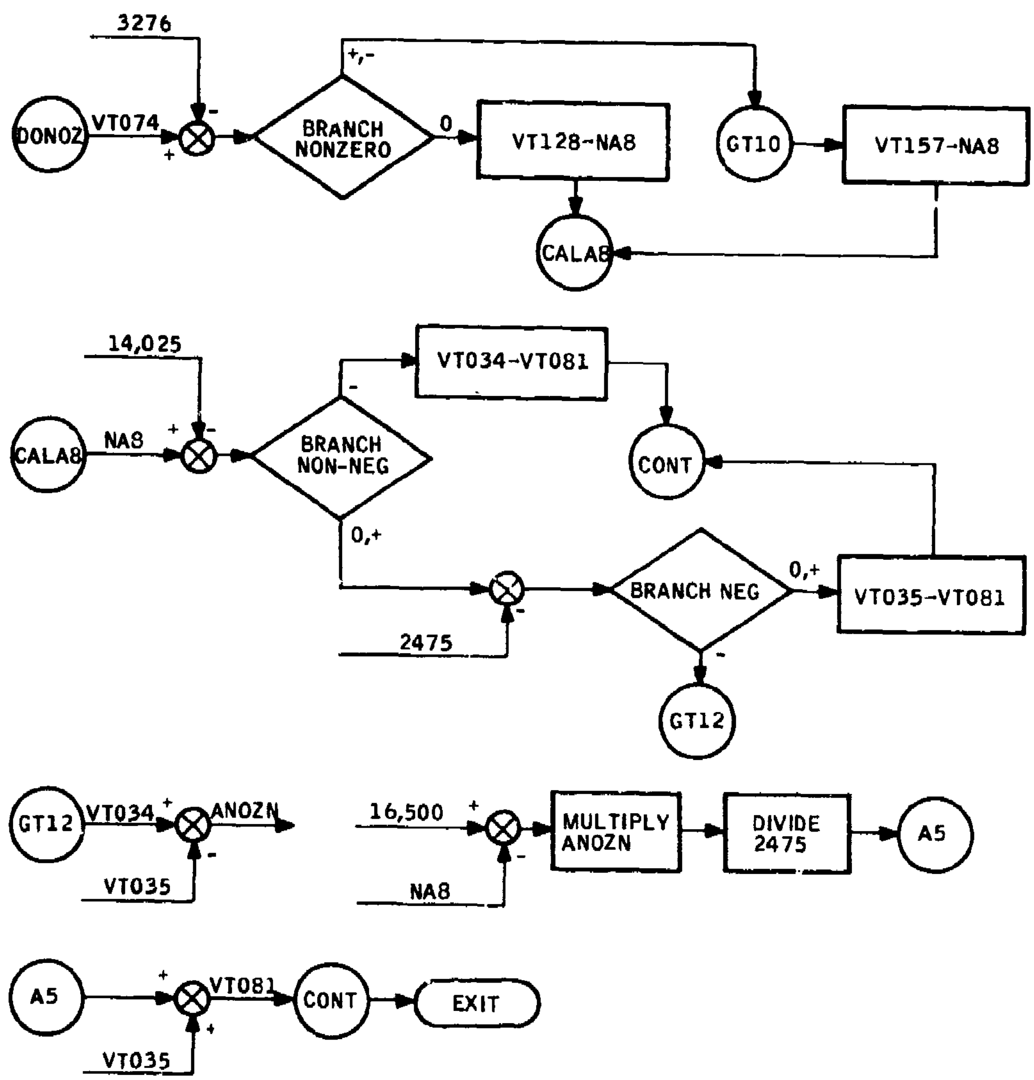

Figure B-11. Exhaust Nozzle Request Calculation

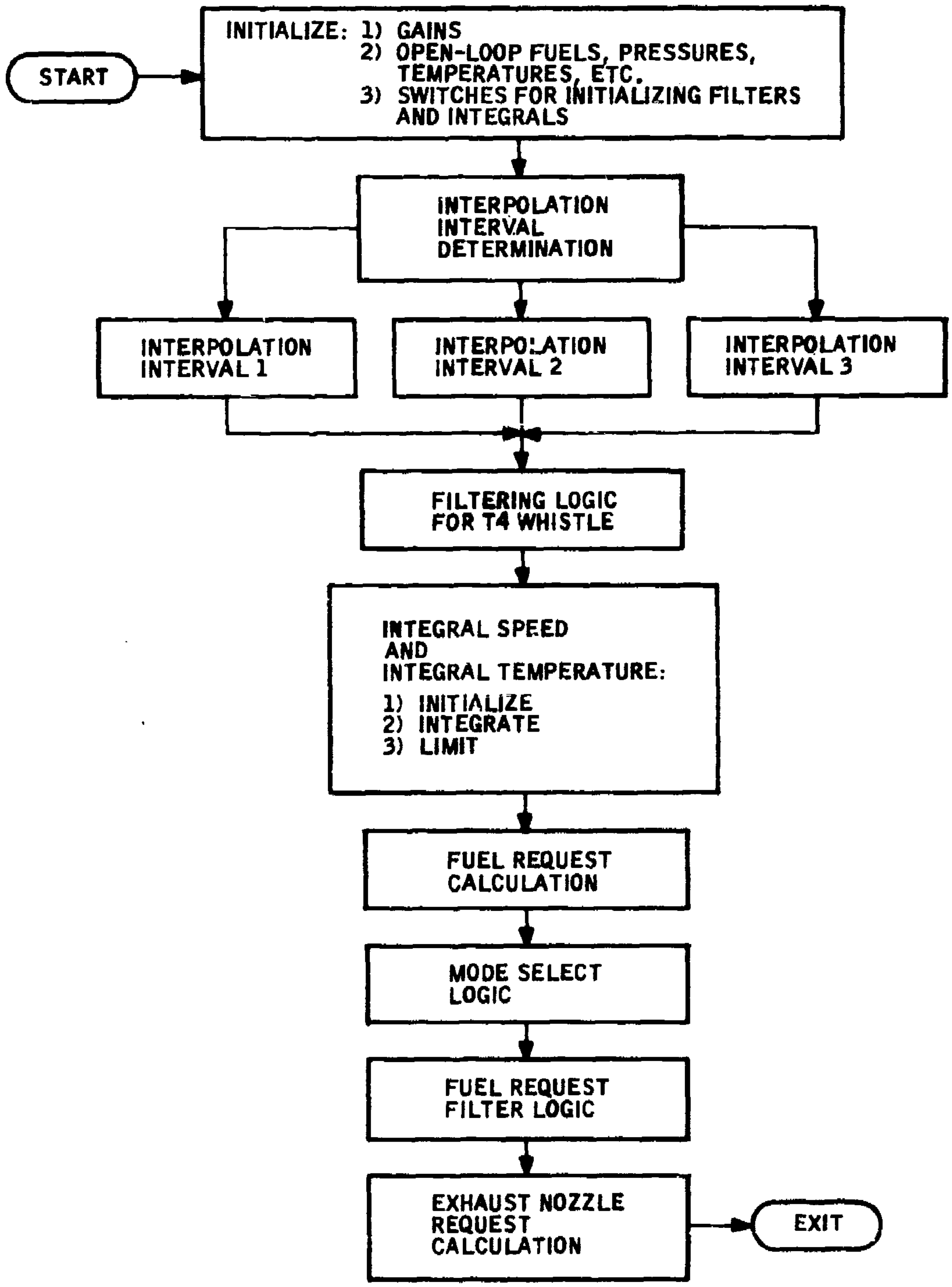

Figure B-12. Functional Flow Diagram Speed and Temperature Control Program

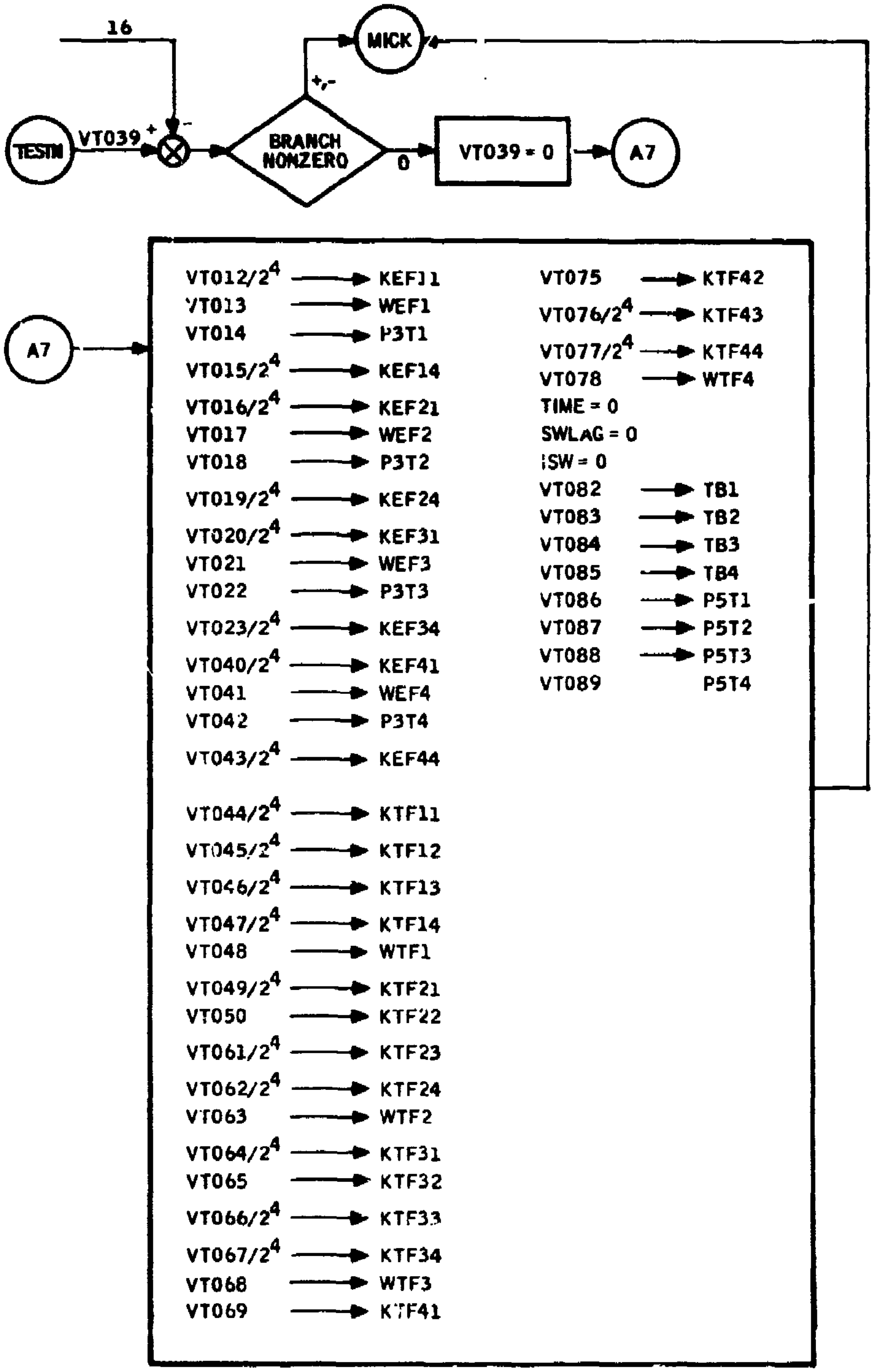

Figure B-13. Initialization Logic for Speed and Temperature Program

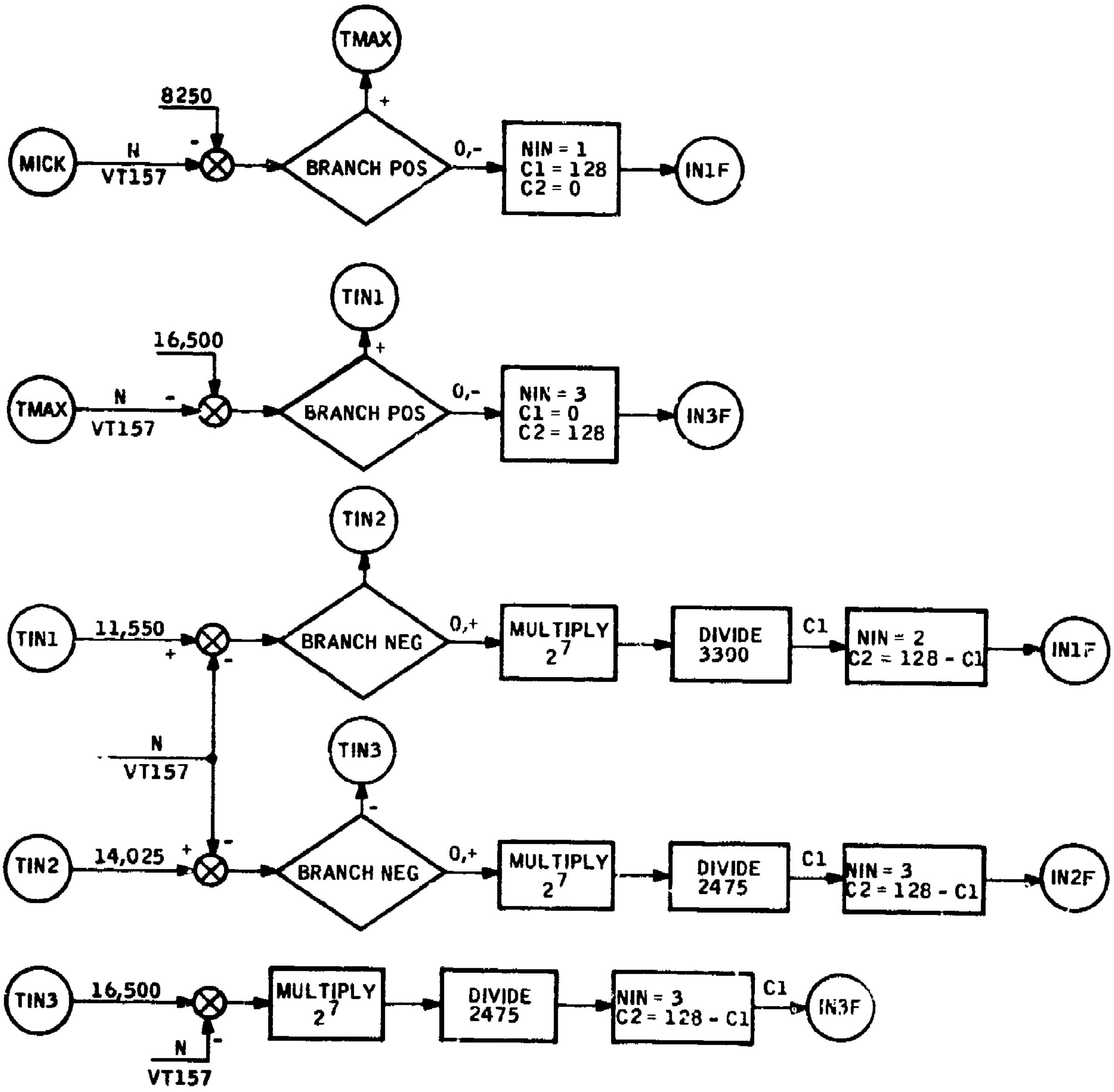

Figure B-14. Interval Determination

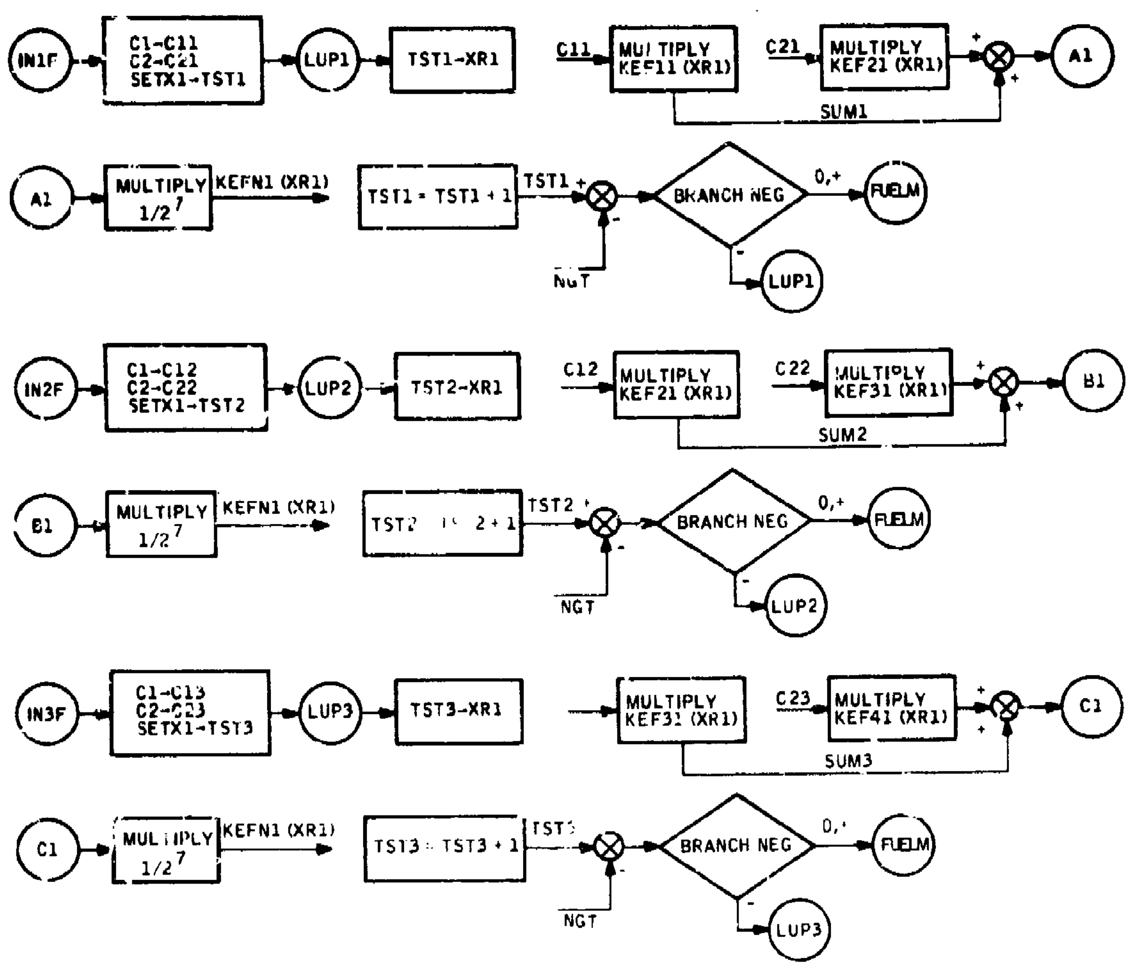

Figure B-15. Interpolation Logic

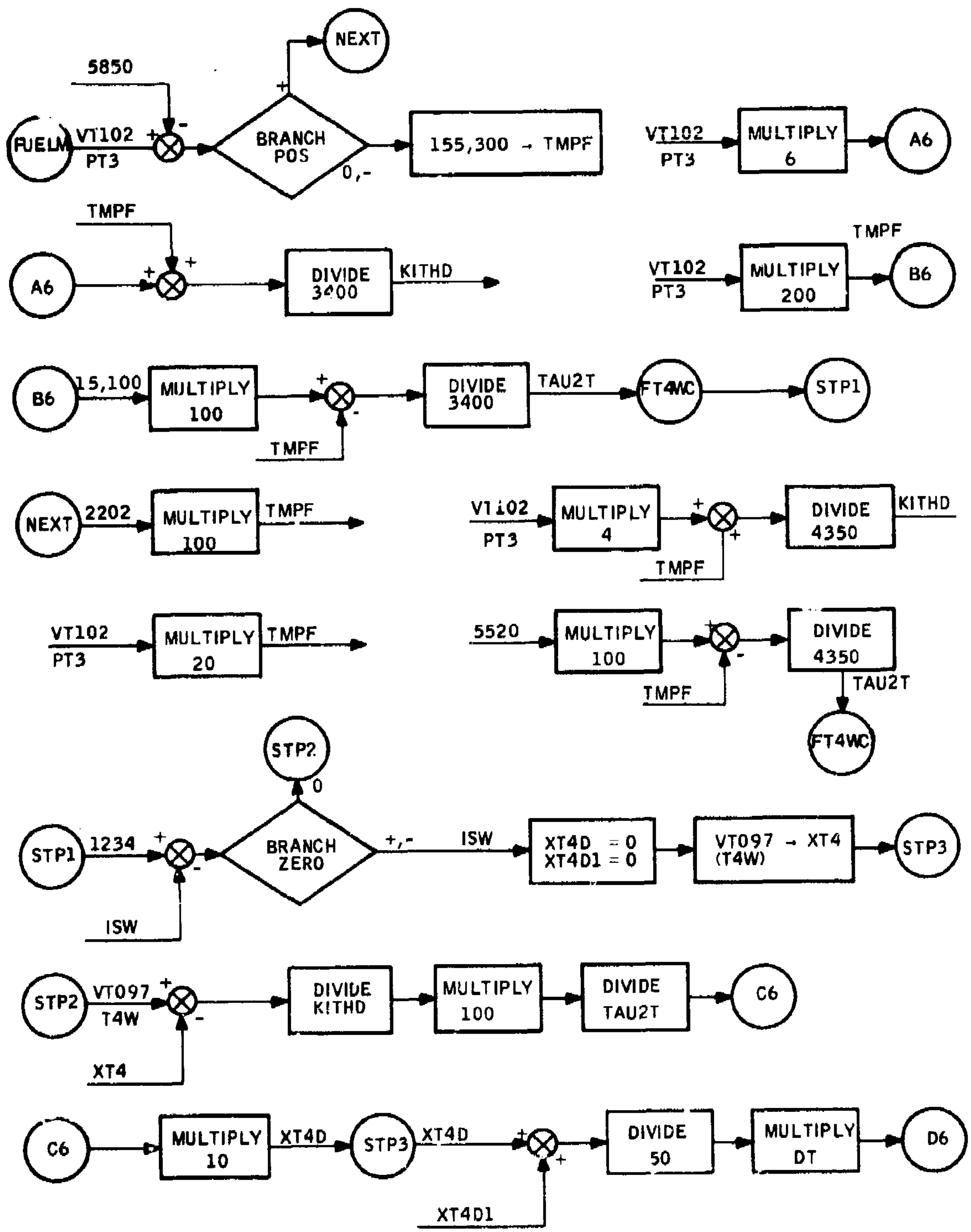

Figure B-16. Filter Logic for T4 Whistle Speed and Temperature Controller

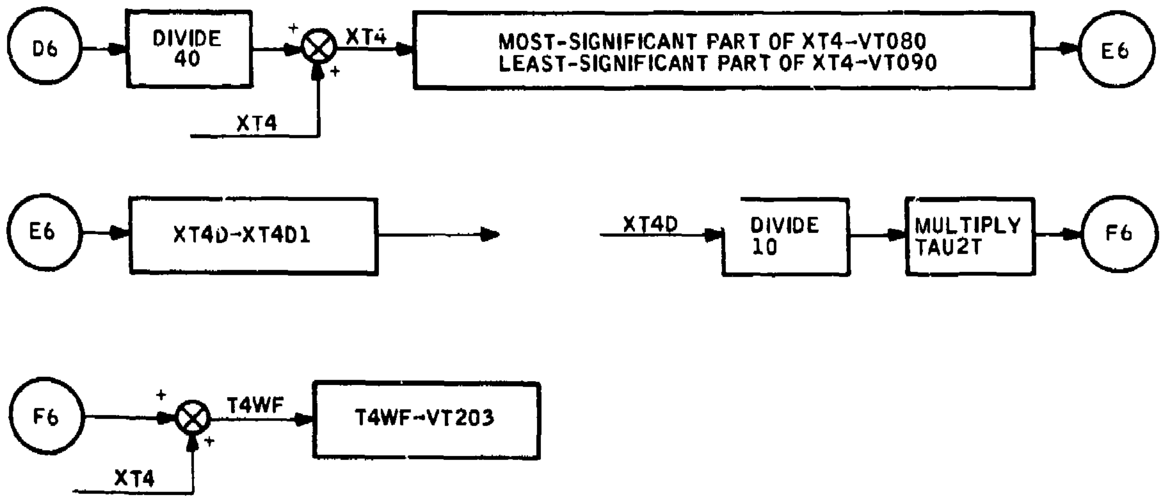

Figure B-16. Filter Logic for T4 Whistle Speed and Temperature Controller (Concluded)

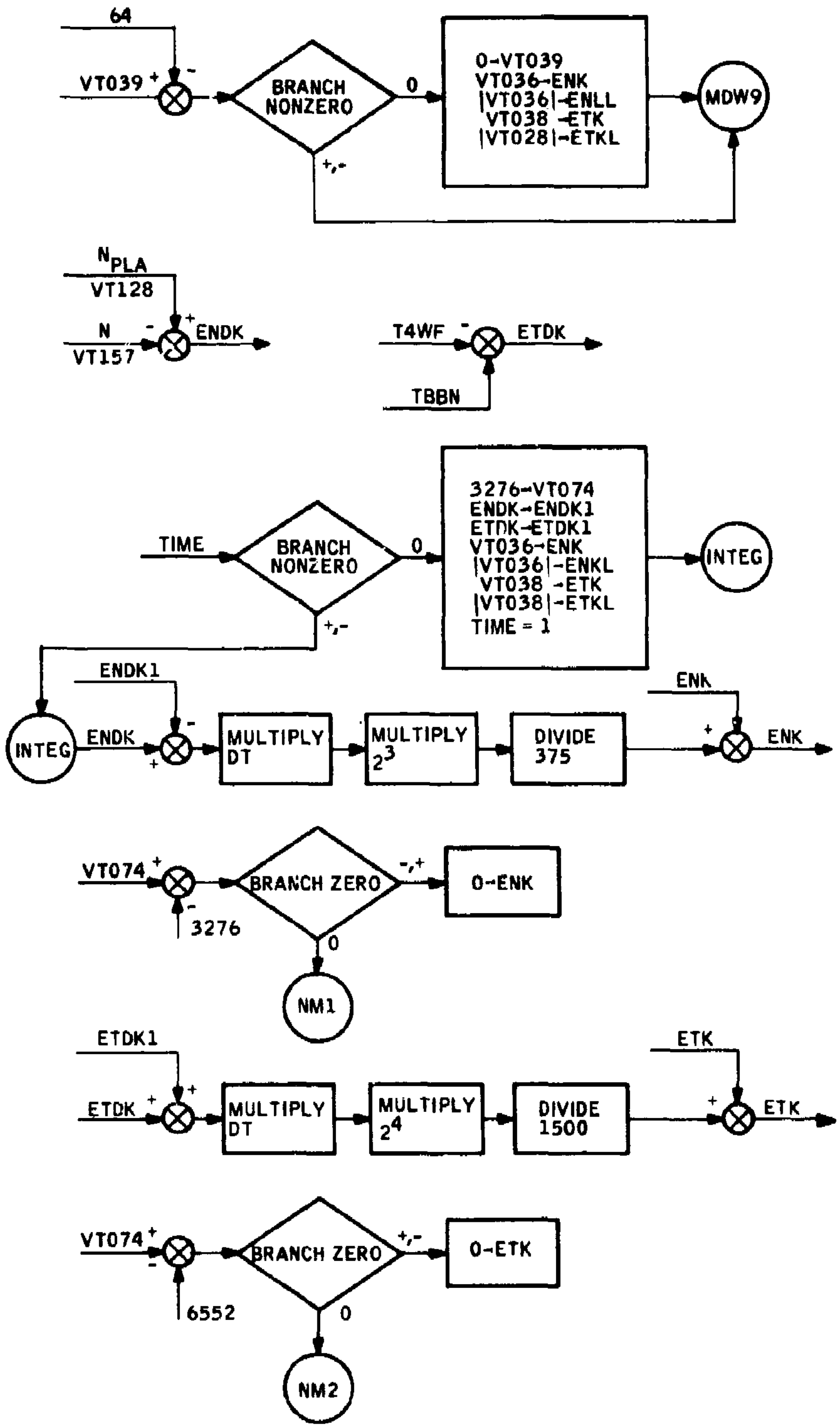

Figure B-17. Integral Speed and Integral Temperature

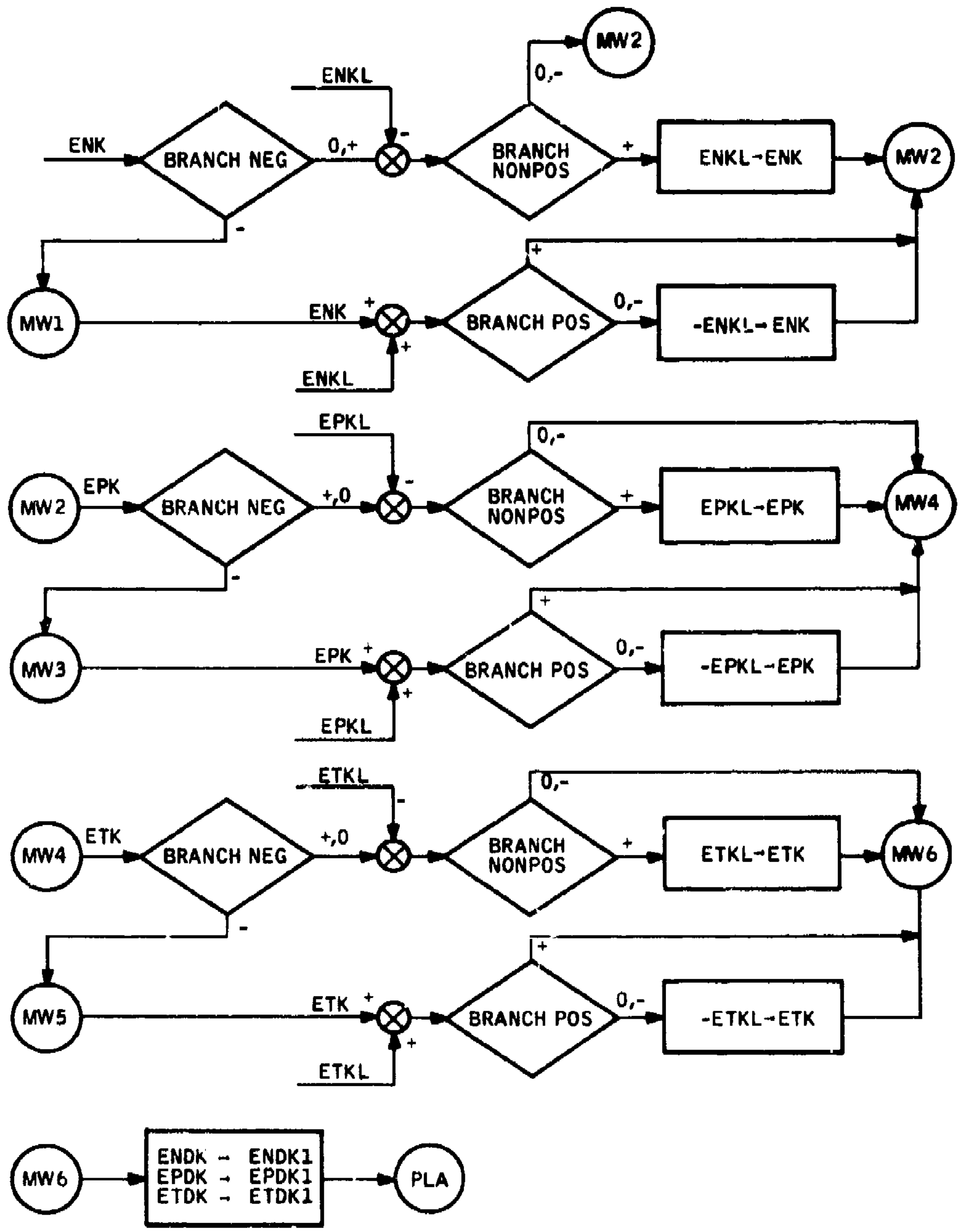

Figure B-18. Limiting Logic for Integral Speed and Integral Temperature

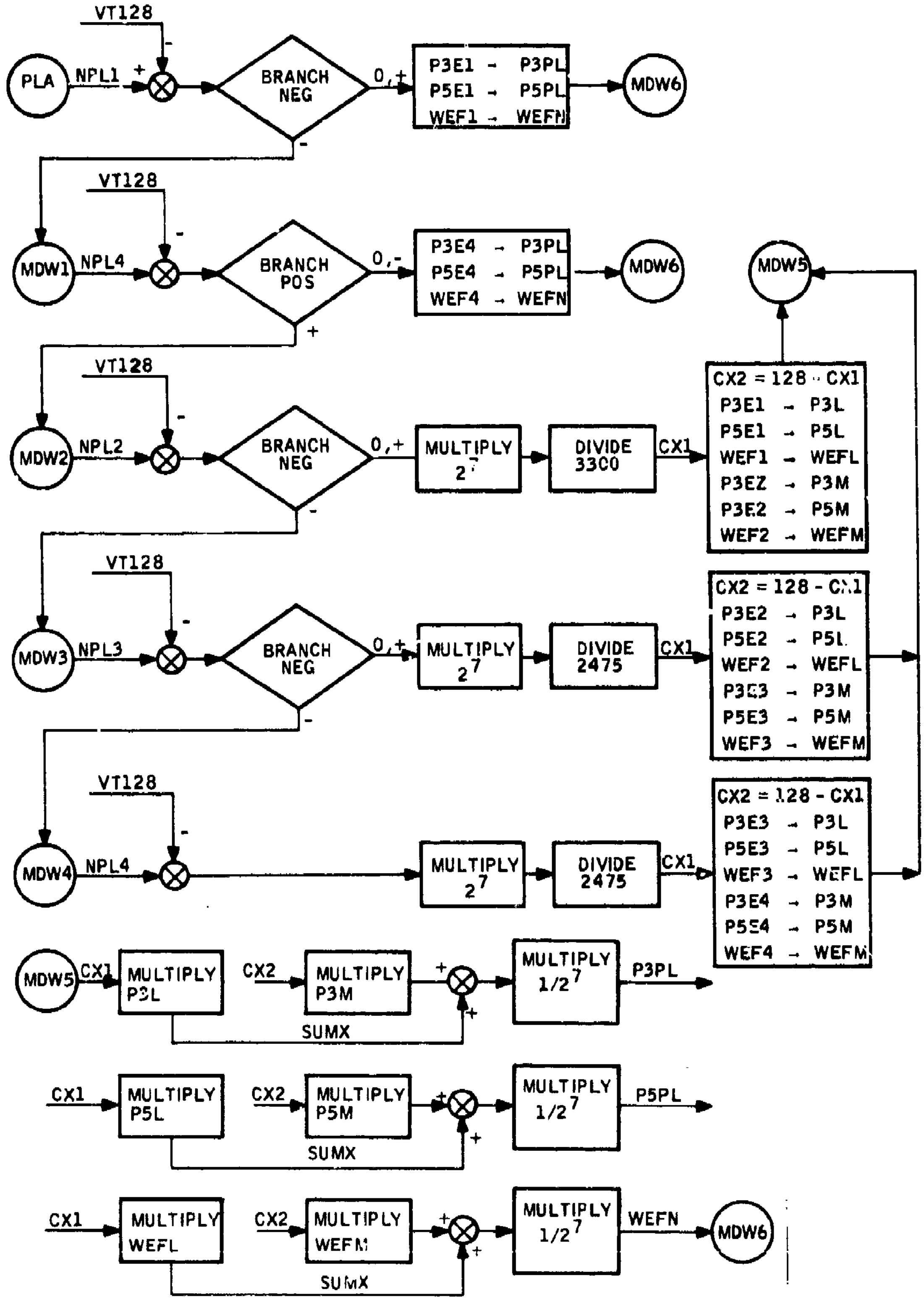

Figure B-19. Interpolation for PT3, PT5 and Fuel Request as a Function of Power Lever

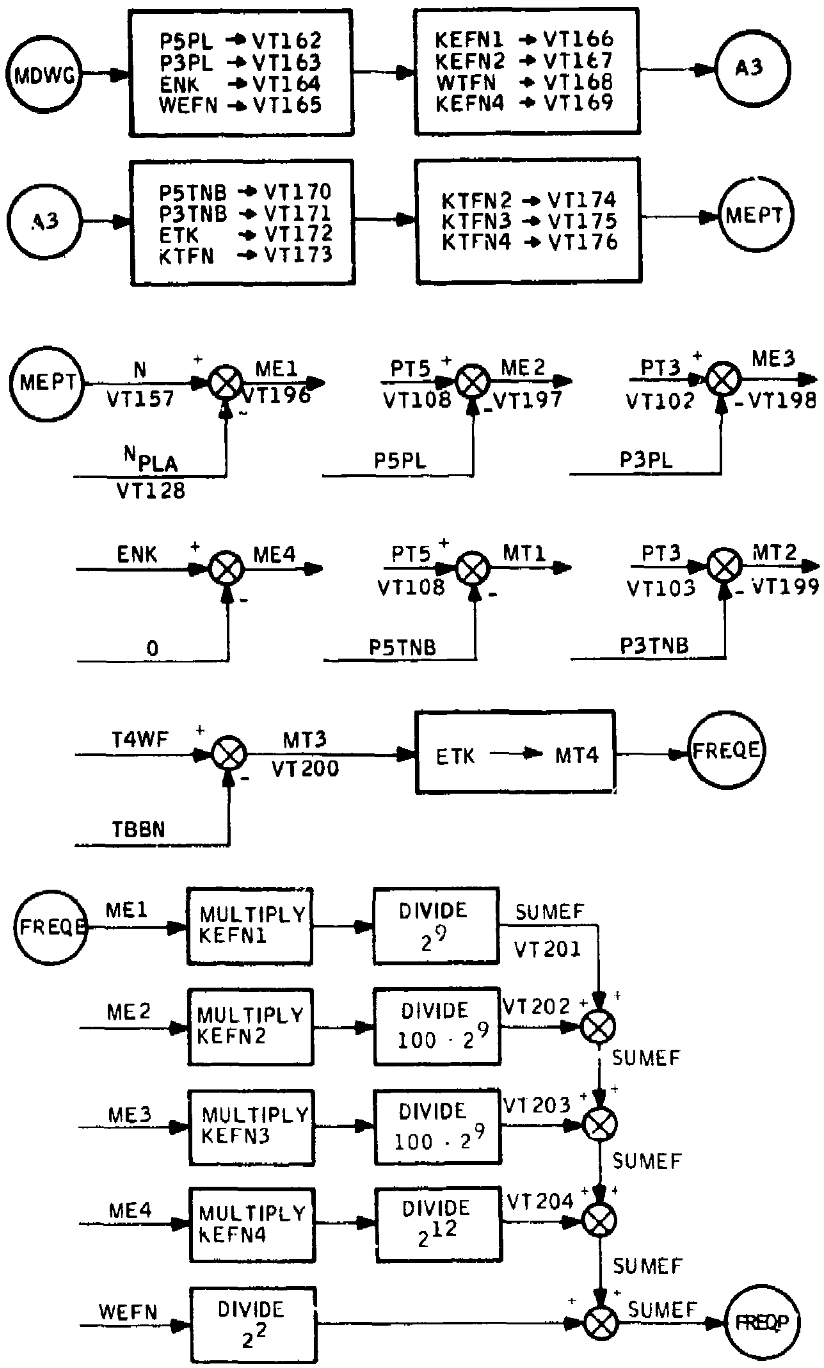

Figure B-20. Fuel Request Calculation

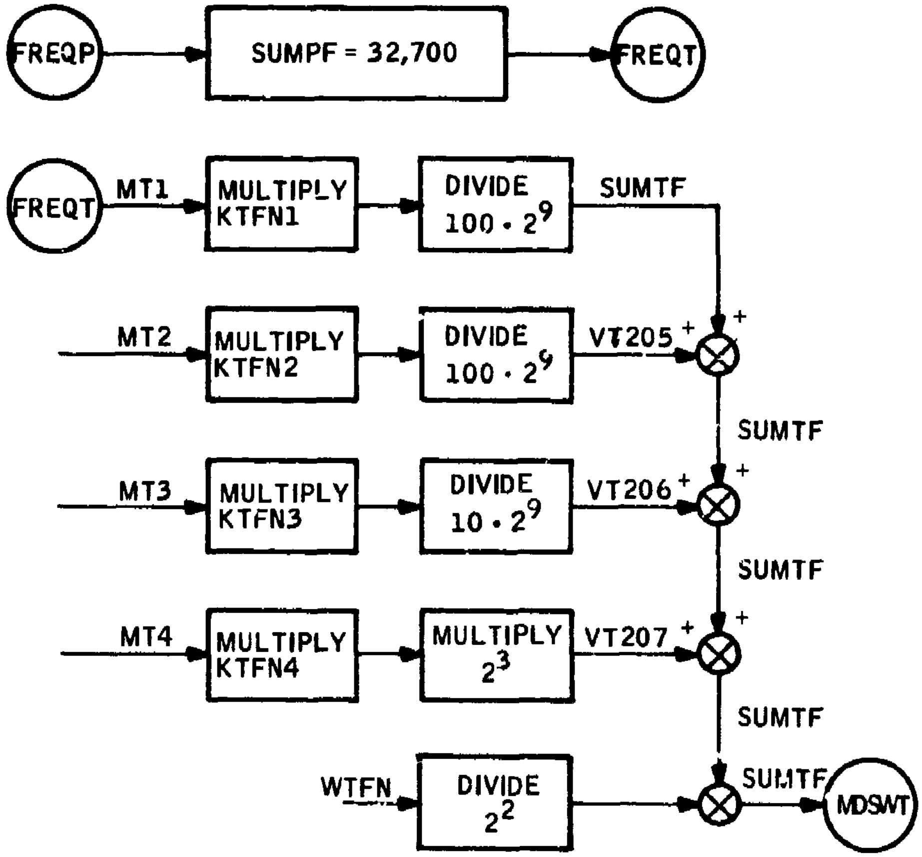

Figure B-20. Fuel Request Calculation (Concluded)

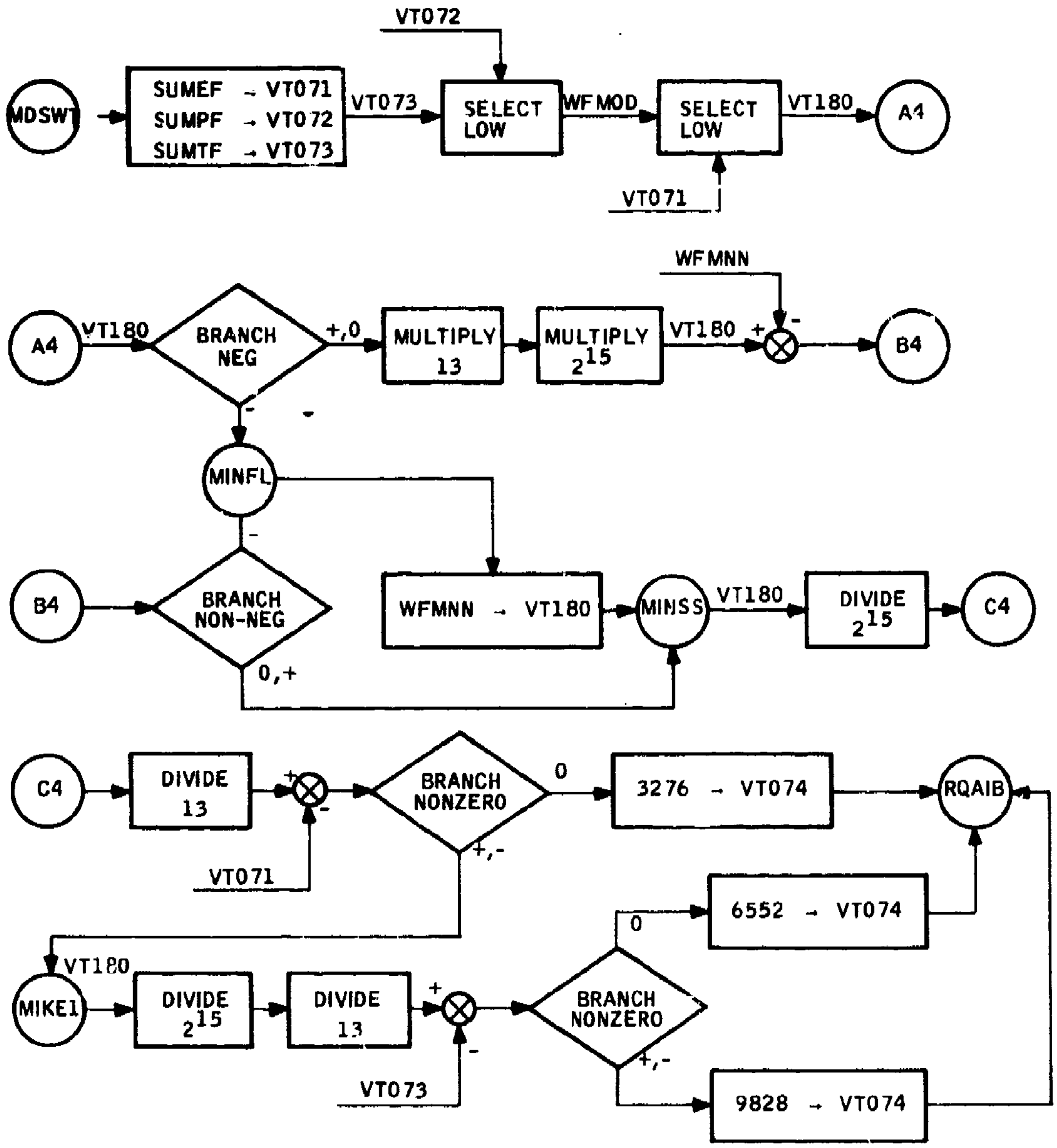

Figure B-21. Mode Select Logic

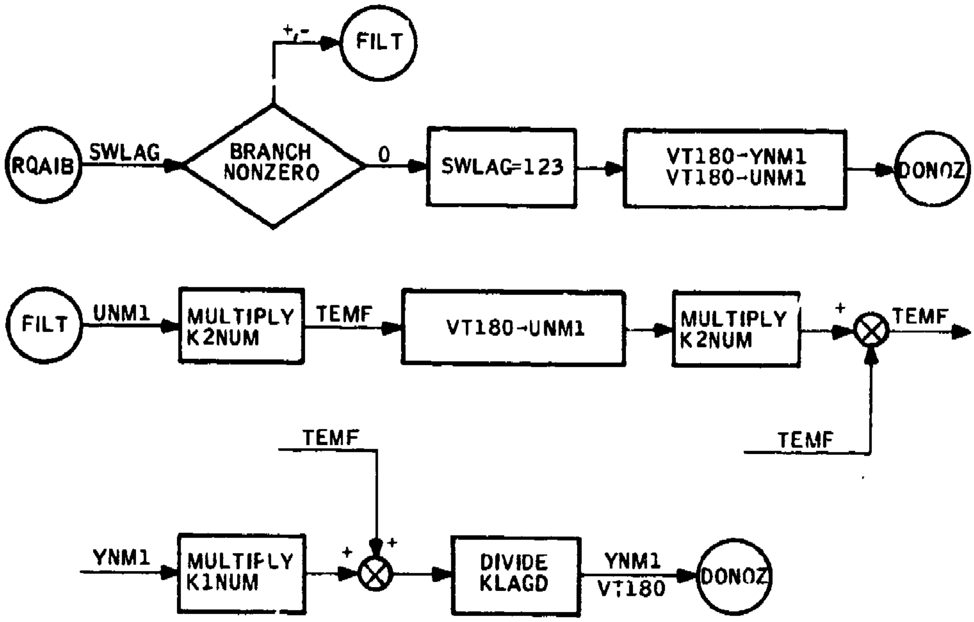

Figure B-22. Fuel Request Filter Logic

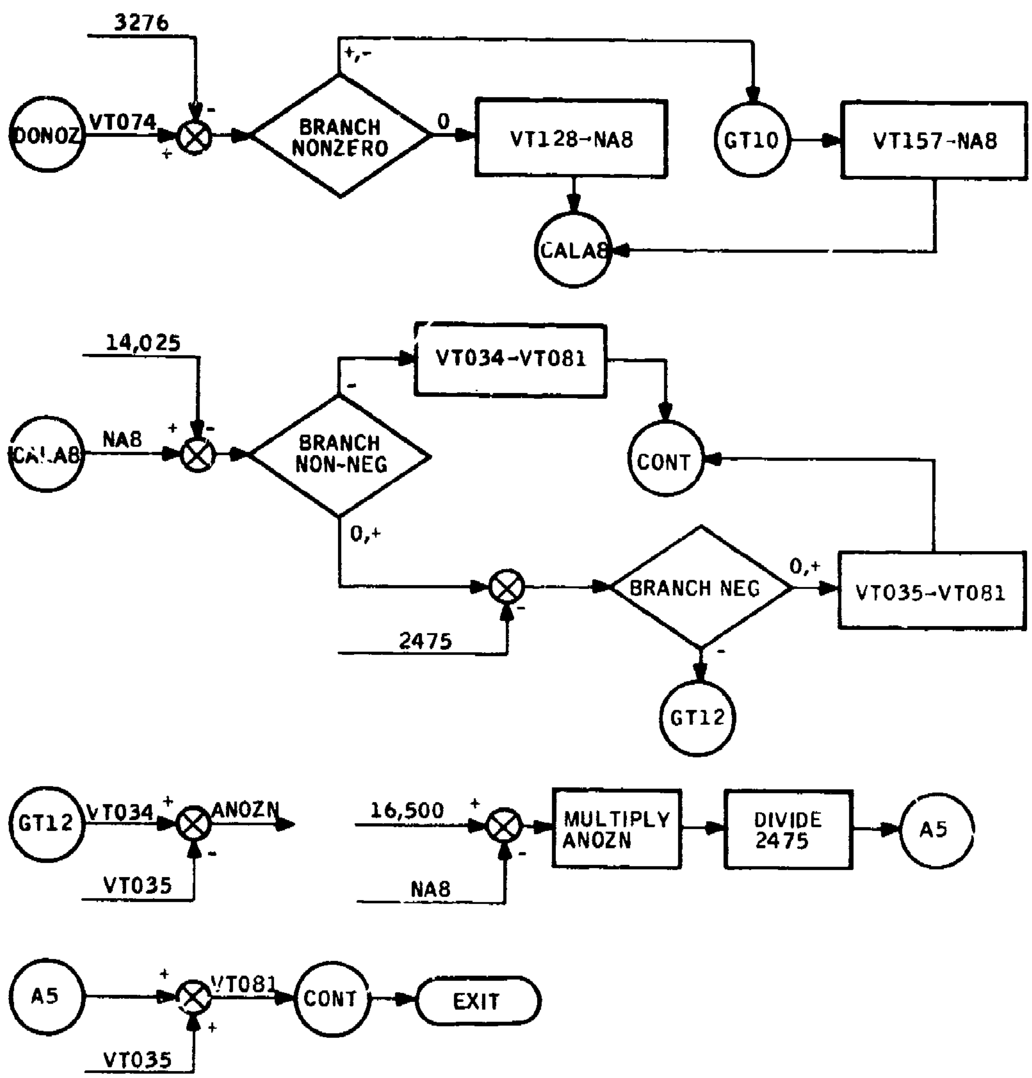

Figure B-23. Exhaust Nozzle Request Calculation

REFERENCES

B-1. Arnett, Samuel E., "Turbine Engine Control Synthesis," AFAPL-TR-74-113, Air Force Aero Propulsion Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, December 1974.

B-2. "IBM 1130/1800 Assembler-Language," GN34-0062, IBM Corporation, Systems Publications, Boca Raton, Florida, October 1971.

APPENDIX C
RATE MODELS FOR INTEGRAL CONTROL

In Sections III and IV of Volume I, a rate model (Reference 5) with integral control (Reference 6) is used in the linear quadratic synthesis (see Table 13 of Volume I).

The model is derived here. Spool speed notation is used although the results are applicable to pressure and temperature.

$$\dot{N} = aN + b\dot{e} + ce + \eta \qquad \text{(C-1)}$$

$$\dot{e} = dN + fP \qquad \text{(C-2)}$$

where

N = Model spool speed
e = Error
P = Model power lever
η = Disturbance

and a, b, c, d and f are constants to be determined to yield good response characteristics. Good response means that (1) N responds to P like a first-order plant, and (2) there is much integral control (sufficient to hold N against steady load disturbances η).

The model is derived in the following equations.

$$\frac{N}{P} = \frac{fb(s + c/b)}{s^2 - (a + bd)s - cd} \qquad \text{(C-3)}$$

$$s = \frac{(a + bd) \pm (a + bd)\sqrt{1 + \frac{4cd}{(a + bd)^2}}}{2} \qquad \text{(C-4)}$$

Choose (a + bd)/2 and λ (C-5, C-6)

Take

$$b = 1.0 \qquad \text{(C-7)}$$

$$c = -b\lambda(a + bd)/2 \qquad \text{(C-8)}$$

$$d = \frac{(a + bd)/2}{b\lambda} \qquad \text{(C-9)}$$

$$a = 2\left(\frac{a + bd}{2}\right) - bd \qquad \text{(C-10)}$$

Then

$$\frac{N}{P} = \frac{f\{s - \lambda(\frac{a + bd}{2})\}}{\{s - (\frac{a + bd}{2})\}^2} \qquad \text{(C-11)}$$

The transfer function and roots for Equations (C-1) and (C-2) are given by Equations (C-3) and (C-4). If the second term in the radical is equal to -1, two identical roots are obtained. This choice is made.

The quantity (a + bd)/2 is chosen equal to the desired pole position.

The value of λ = 0.75 yields an excellent approximation to first-order response.

Coefficient data are presented below. Equations (C-7), (C-8), (C-9), and (C-10) yield a, b, c and d; is then selected by use of Equation (C-2) to yield the correct steady-state relationship between N and P.

Equation (C-11) presents the resulting transfer function. It is seen that λ positions the zero relative to the poles.

Coefficient data

Root	a	b	c	d
-2.0	-1.3333	+1.0	+1.5	-2.6667
-4.0	-2.6667	+1.0	+3.0	-5.3333
-10.0	-6.6667	+1.0	+7.5	-13.333

APPENDIX D
SIMPLE OPTIMIZATION

A derivation is presented of the algorithm used for control simplification (e.g., paragraph 3, page 131 through paragraph 2, page 134 of Volume I for simple speed control). This derivation is a slight modification of the original (pp. 7 - 19 of Reference D-1). The source program is listed in Appendix I of Reference D-1.

The algorithm has more capability than was used on the Turbine Engine Control Synthesis contract. On this contract, the algorithm was used to find the optimal (simple) gains at each of 12 operating conditions (four each for speed, pressure, and temperature). The algorithm could have been used to determine (say) the best single value of P3 gain (over the 12 operating conditions), while the other gains (N, EN, PT5, etc.) were optimized at each of the 12 operating conditions. In this case, the P3 gain is "fixed" and the N, EN, etc., gains are variable; hence, the Reference D-1 name for the algorithm: "Fixed-Plus-Variable Gain (FPVG)." For this turbine control synthesis, the fixed-gain feature was suppressed by working each operation condition separately.

BACKGROUND

The fixed-plus-variable (simple optimization) quadratic design procedure helps to solve a technical problem which confronts the major technical issues of engine control system design:

- High dimensionality
- Simplification
- Variability

High dimensionality is the reason the design procedure employs the theory of quadratics. This theory has been used before, on the B-52 LAMS (Ref. D-2), the C-5A LAMS (Ref. D-3), and the YF-12 LAMS (Ref. D-4). All of these programs involved design of flexure control, where the dynamic order of the models could be truncated to no less than 20 to 30 states.

Simplification arises because optimal quadratics, while promising solutions to dimensionality, yield control systems of substantial complexity. They demand feedbacks from all states to all controls. It is necessary to incorporate the constraints of measurement feasibility and control complexity into the fixed-plus-variable design procedure. These constraints were incorporated on the YF-12 LAMS program for single flight conditions and on the F-4 Lateral Axis program (Ref. D-5) for single and multiple flight conditions with fixed gains.

The third problem confronted is that of variability with respect to aerodynamic parameters, vehicle configuration, and mass distribution. Fixed gains were used on the F-4 Lateral-Axis program over an entire flight envelope, but the controller performance suffered because of it, even though the aircraft does not have flexure problems as do the B-52 and YF-12. On this contract (Ref. D-1), we use fixed-plus-variable gains to alleviate the problem of variability.

The formulation of the fixed-plus-variable quadratic design procedure, and the computational techniques used in the procedure, are discussed in this Appendix.

PROBLEM FORMULATION

The aircraft is represented at various points of the flight envelope and for various configurations and mass distributions by a collection of p frozen-point linear plants:

$$\frac{dx_i}{dt} = F_i x_i + G_{1i} u_i + G_{2i}\, \eta \qquad \text{(D-1)}$$

$$r_i = H_i x_i + D_i u_i \qquad i = 1, \ldots, p \qquad \text{(D-2)}$$

$$y_i = M_i x_i$$

Here x_i is the state vector for plant i which, for flexible aircraft, includes the following dynamics:

- Rigid-body states
- Actuator and servo states
- Significant flexure-mode states
- Low-frequency sensor states
- Model states (if state model-following is used)
- Küsner and Wagner states (associated with unsteady aerodynamics)
- Wind states (associated with atmospheric gust models).

The vector u_i represents control variables, η is a unity variance white noise vector, r_i is a vector of responses to be controlled (stresses and stress rates, accelerations at selected fuselage stations, model-following errors, control magnitudes and rates, etc.), and y_i is a vector of measurements (accelerometer outputs, gyro outputs, etc.). The matrices F_i (open-loop stability matrix), G_{1i} (control input matrix), G_{2i} (disturbance input matrix), H_i (response output matrix), D_i (control output matrix) and M_i (measurement matrix) are of appropriate order.

The above enumeration of components, vectors, and matrices is for an airplane for which Reference D-1 was concerned. Tables 40, 41, and 42 of Volume 1 list comparable items for turbine control synthesis.

We now look for a time-invariant controller of the form

$$u_i = K_i y_i \qquad \text{(D-3)}$$

such that the following performance index is minimized:

$$J = \sum_{i=1}^{p} \alpha_i J_i \qquad \text{(D-4)}$$

where

$$J_i = E\left\{\mathrm{Tr}\left[Q_i r_i r_i^T\right]\right\} \qquad i = 1, 2, \ldots, p \qquad \text{(D-5)}$$

Here E $\{\cdot\}$ denotes expectation, Tr $[\cdot]$ is the trace operator, and $(\cdot)^T$ denotes transpose of $(\cdot)$.

The Q_i are quadratic weights for flight condition i which are selected through quadratic equivalence or by means of a few trial design iterations (the art of the design procedure). The α_i are flight-condition weights selected as needed. A few suggestions about how to select them appears later in the discussion of the specific examples. The cost functional J is a generalization of the standard quadratic performance index of a single plant and represents a weighted performance over the flight envelope.

For turbine control synthesis, an operating condition corresponds to a flight condition in aircraft control synthesis. An operating condition for turbine synthesis is given by: (1) equilibrium speed control at (2) sea level static at (3) 70-percent power lever setting.

The gains matrices K_i are in general of the form

$$K_i = K^1 + K_i^5 \qquad i = 1, \ldots, 1 \qquad \text{(D-6)}$$

where K^1 is a matrix of fixed gains constant over the flight envelope, and K_i^5 are the matrices of variable gains which vary over the flight envelope. For a fixed-gain design, the K_i^5 are empty.

The necessary conditions for the optimality of the K_i are obtained from the Maximum Principle (Ref. D-6). Let us rewrite the performance index as

$$J = \sum_{i=1}^{p} \alpha_i \mathrm{Tr} \left\{ \left[H_i + D_i K_i M_i\right]^T Q_i \left[H_i + D_i K_i M_i\right] X_i \right\} \tag{D-7}$$

where the covariance matrices

$$X_i = E\left[x_i x_i^T\right], \qquad i = 1, \ldots, p \tag{D-8}$$

are solutions of the Lyapunov equations

$$0 = \left[F_i + G_{1i} K_i M_i\right] X_i + X_i \left[F_i + G_{1i} K_i M_i\right]^T, \quad i = 1, \ldots, p \tag{D-9}$$

Equations (D-7) and (D-9) are used to define a Hamiltonian:

$$\begin{aligned} H = \sum_{i=1}^{p} \Big\{ & \alpha_i \mathrm{Tr}\left[H_i + D_i K_i M_i\right]^T Q_i \left[H_i + D_i K_i M_i\right] X_i \\ & + \mathrm{Tr} S_i^T \Big[\left(F_i + G_{1i} K_i M_i\right) X_i + X_i \left(F_i + G_{1i} K_i M_i\right)^T \\ & + G_{2i} G_{2i}^T \Big]\Big\} \end{aligned} \tag{D-10}$$

H is differentiated with respect to the covariance matrices X_i, the adjoint matrices S_i, and with respect to all the nonconstrained gains of the matrices K^1 and K_i^5. The necessary conditions for optimality for this fixed-plus-variable-gain control are:

- $$\frac{\partial H}{\partial S_i} = \left(F_i + G_{1i}K_iM_i\right)X_i + X_i\left(F_i + G_{1i}K_iM_i\right)^T + G_{2i}G_{2i}^T = 0; \qquad i = 1, \ldots, p \tag{D-11}$$

- $$\frac{\partial H}{\partial X_i} = \left(F_i + G_{1i}K_iM_i\right)^T S_i + S_i\left(F_i + G_{1i}K_iM_i\right) + \alpha_i\left(H_i + D_iK_iM_i\right)^T Q_i\left(H_i + D_iK_iM_i\right) = 0; \tag{D-12}$$

  $i = 1, \ldots, p$

- $$\frac{\partial H}{\partial K^1_{\ell m}} = \left\{\sum_{i=1}^{p}\left[\alpha_i D_i^T Q_i\left(H_i + D_iK_iM_i\right) + G_{1i}^T S_i\right]X_iM_i^T\right\}_{\ell m} = 0 \tag{D-13}$$

for all nonconstrained elements $K^1_{\ell m}$ of fixed matrix K^1.
(In the above, $\{A\}_{\ell m}$ denotes the ℓm^{th} element of matrix A.)

- $$\frac{\partial H}{\partial K^5_{\ell mi}} = \left\{\left[\alpha_i D_i^T Q_i\left(H_i + D_iK_iM_i\right) + G_{1i}^T S_i\right]X_iM_i^T\right\}_{\ell m} = 0; \tag{D-14}$$

$i = 1, \ldots, p$, for all nonconstrained elements $K^5_{\ell mi}$ of the variable-gain matrices K_i^5.

- $$K_i = K^1 + K_i^5; \qquad i = 1, \ldots, p \tag{D-15}$$

COMPUTATIONAL SOLUTION

The solutions of Equations (D-11) through (D-14) obviously do not exist in closed form. Thus, an iterative gradient search is necessary.

Equations (D-11) and (D-12) are solved quite readily for arbitrary gains matrices K_i through the use of computer algorithms that have been available for some time (such as explained in Ref. D-7). The solutions of these equations, the X_i and S_i, are used in the computation of the gradient components of Equations (D-13) and (D-14).

The development of the iterative gradient search algorithm to solve Equations (D-13) and (D-14) was the main effort of this contract.

A Newton-Raphson gradient technique was already developed and used for a fixed-gain design on the F-4 Lateral-Axis program (Ref. D-5); however, for the fixed-plus-variable quadratic design, the number of components in Equation (D-14) can be quite large, causing insurmountable computational difficulties with that technique, because it requires a matrix of second partial derivatives.

Computing a matrix of second partial derivatives requires solving a Lyapunov equation for each fixed gain and for each variable gain for each flight condition.

Other problems encountered with the Newton-Raphson gradient technique can be solved with a variable stepsize.

In view of the problems with this gradient technique, we decided to go with the straight gradient search, computing no second partial derivatives, and using a variable stepsize. We did, however, use some ideas of the predictor corrector scheme in implementing the gradient search. This resulted in what we call the incremental gradient.

INCREMENTAL GRADIENT

Let $K_i(\lambda)$ be the gain matrix for plant i defined as

$$K_i(\lambda) = K^1(\lambda) + K_i^5(\lambda) + \lambda K_i^2;\ 0 \leq \lambda \leq 1;\ i = 1, \ldots, p \qquad \text{(D-16)}$$

and let

$$K_i(1) = K^1(1) + K_i^5(1) + K_i^2 \qquad \text{(D-17)}$$

be the optimal quadratic gains for plant i on the measurements y_i found through the solution of the Riccati Differential Equation,* and let

$$K_i(0) = K^1(0) + K_i^5(0) = K^1 + K_i^5 = K_i \qquad \text{(D-18)}$$

be the final gains matrix for plant i. The expression λ is a scalar parameter; K^1 and K_i^5 are found by using the incremental gradient procedure which starts with initial gains $K^1(1)$ and $K_i^5(1)$; K_i^2 are simply the difference between the optimal gains $K_i(1)$ and initial gains $K^1(1) + K_i^5(1)$.

In terms of Equation (D-16), the necessary conditions for optimality of K^1 and K_i^5 are that

$$\left.\frac{\partial J[K_i(\lambda)]}{\partial K^1}\right|_{\lambda = 0} = 0 \qquad \text{(D-19)}$$

and

$$\left.\frac{\partial J[K_i(\lambda)]}{\partial K_i^5}\right|_{\lambda = 0} = 0 \qquad \text{(D-20)}$$

*This requires that the M_i be square and nonsingular. They can be made so by adding direct measurements of states not necessarily measurable.

In fact, if we start with $\lambda = 1$ and satisfy Equations (D-19) and (D-20) for all λ in $[0, 1]$, Equations (D-19) and (D-20) are certainly true for $\lambda = 0$. At the same time, we are ensuring with high probability that a global minimum of $J(K^1 + K_i^5)$ is reached because we are starting in the "deepest valley of J" and forcing λ to zero along the trajectory $\{K^1(\lambda),\ K_i^5(\lambda),\ K_i^2;\ 1 \geq \lambda \geq 0\}$. Since we are then "on the walls of the deepest valley," along with the knowledge of $J[K_i(1)]$ and $J[K^1(0) + K_i^5(0)]$, we can terminate the search for the global minimum.

Stein and Henke (Ref. D-5) used the Implicit Function Theorem which defined K^1 (in their case it was fixed gains only) from the solution of the differential equation

$$\frac{dK^1(\lambda)}{d\lambda} = -\left[\frac{\partial^2 J(K^1 + \lambda K^2)}{\partial K^1 \partial K^{1T}}\right]^{-1} \frac{\partial^2 J(K^1 + \lambda K^2)}{\partial K^1 \partial \lambda} \qquad \text{(D-21)}^*$$

by starting with the known terminal condition $K = K^1 + K^2$ for $\lambda = 1$ and integrating it backward toward $\lambda = 0$. The method of numerical integration used was that which used an Adams-Moulton Predictor and a Newton-Raphson Corrector to step λ from 1 to 0.

The main problem with this procedure is that the evaluation of the second partial derivatives is very costly, and gets out of hand when the variable gains are included. Another problem is that the predictor or corrector steps are sometimes too big and can cause one plant or another to go unstable. The incremental gradient procedure alleviates this problem by approximating the second partial derivatives (discussed later), using a simple linear predictor, and a variable step size on the corrector. More than one gradient direction per prediction step and the variable gradient step size more than make up for the approximation and prediction simplification.

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*K, K^1 and K^2 must be stacked up as column vectors for this equation to make sense. This is assumed.

The incremental gradient procedure is summarized in Figure D-1 for a single-plant problem. Here, λ is stepped to zero in five steps. There are only two gains, K^1 and K^2. We wish to eliminate K^2. However, if we eliminate K^2 without changing K^1, the system is unstable, and a gradient direction cannot be found. (This frequently happens in real-world problems.)

The first prediction step is in the K^2 direction only. (In practice, this never presented a problem.) A correction is made with a Newton-Raphson gradient search using approximate second partial derivatives and a variable step size determined from a parabolic fit. The subsequent predictions are extrapolations from the initial point through the last correction points. The process continues for each step in λ.

The predicted gains are

$$K_p^{\ 1}(\lambda_{j+1}) = K_c^{\ 1}(\lambda_j) + \left[K_c^{\ 1}(\lambda_j) - K_c^{\ 1}(\lambda_{j-1})\right] \tag{D-22}$$

and

$$K_{ip}^{\ 5}(\lambda_{j+1}) = K_{ic}^{\ 5}(\lambda_j) + \left[K_{ic}^{\ 5}(\lambda_j) - K_{ic}^{\ 5}(\lambda_{j-1})\right]; \quad i = 1, \ldots, p \tag{D-23}$$

where λ_j is the value of λ on the j^{th} predictor step, and the initial prediction is zero. The "c" and "p" denote "corrected" and "predicted." The predicted gains are the initial gains for the gradient search. The corrected gains result from the gradient search.

For the variable step size for the gradient search, the performance index J is computed for three step sizes -- 0, ϵ_1, and $2\epsilon_1$ -- and fit to a parabola

$$J(\epsilon) = J(0) + A\epsilon + B\epsilon^2 \tag{D-24}$$

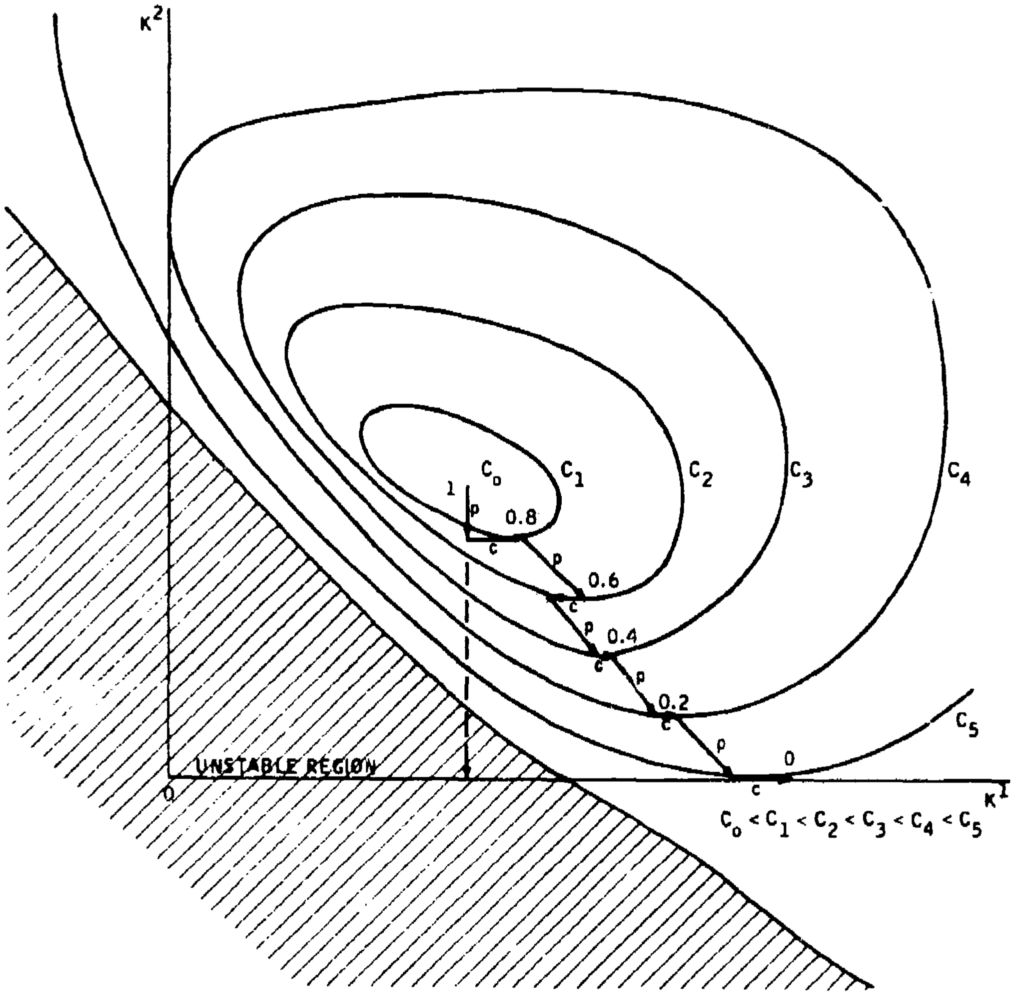

Figure D-1. Incremental Gradient Path

A minimum at

$$\epsilon = -\frac{A}{2B} \qquad \text{(D-25)}$$

is computed, where A and B are a function of the performances $J(0)$, $J(\epsilon_1)$, $J(2\epsilon_1)$ and ϵ_1. The logic for halving and doubling the step size for computing these performances is discussed in Appendix I of Reference D-1.

THE GRADIENT TRANSFORMATION

An aircraft example presented a situation that exists on many minimization problems. That is, the performance contours are extremely ellipsoidal. This causes a straight gradient search to converge very slowly or not even noticeably. The ideal situation is to have the performance contours be spheroidal. Then the gradient direction would be right to the center of the spheroid. This is shown in Figure D-2.

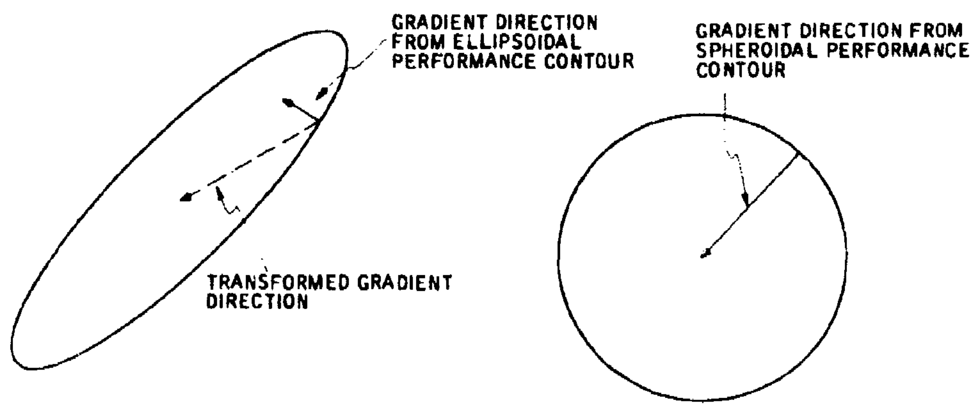

Figure D-2. Comparison of Gradient Directions for Two Performance Contours

If a performance contour is extremely ellipsoidal, the effect of a spheroidal contour can be realized by transforming the gradient vector. This effect is also shown in Figure D-2.

For a problem with a second-order minimum, the ideal transformation is that provided by the Newton-Raphson gradient direction, that is, the inverse of the matrix of second partial derivatives. However, as stated before, the evaluation of the second partial derivatives is very costly. Thus, an approximation was used that works extremely well.

An element in the matrix of second partial derivatives may be written as (assuming for the moment only a fixed-gains matrix for a single flight condition stacked up as vectors):

$$\frac{\partial^2 J(K)}{\partial K_{ij}^{\;1}\partial K_{\ell m}^{\;1}} = 2R_{i\ell} M_j X M_m^{\;T} + 2\sum_{k=1}^{n}\left[(K^T R)_{ki} + (SG_1)_{ki}\right] M_j \left(\frac{\partial X}{\partial K_{\ell m}^{\;1}}\right)_k$$

$$+ 2\sum_{k=1}^{n}\left[(K^T R)_{k\ell} + (SG_1)_{k\ell}\right] M_m \left(\frac{\partial X}{\partial K_{ij}^{\;1}}\right)_k \qquad \text{(D-26)}$$

where X is the state covariance matrix, S is the adjoint matrix and

$$R = D^T Q D \qquad \text{(D-27)}$$

M_k denotes row k of M, and $(\partial X/\partial K_{ij}^{\;1})_k$ denotes the k^{th} column of the partial derivative of X with respect to $K_{ij}^{\;1}$.

The approximation neglects the last two terms of Equation (D-26) because the partial derivatives $(\partial X/\partial K_{ij}^{\;1})$ require a Lyapunov equation solution for each element in K^1. This approximation is not a bad one, for the two terms take

care of any warping due to the change in X with respect to K_{ij}^{1}, and additional gradient directions will take care of this warping.

To extend this transformation to the fixed-plus-variable design, it must include the cross-correlation between measurements with fixed gains and measurements with variable gains. To do this, the gradient vectors for each of r controls must be stacked up end to end to form a vector

$$\frac{\partial J}{\partial K} = \begin{bmatrix} \dfrac{\partial J^T}{\partial K_1^{1}} \\ \vdots \\ \dfrac{\partial J^T}{\partial K_r^{1}} \\ \vdots \\ \dfrac{\partial J_1^{T}}{\partial K_{11}^{5}} \\ \vdots \\ \dfrac{\partial J_1^{T}}{\partial K_{r1}^{5}} \\ \vdots \\ \dfrac{\partial J_p^{T}}{\partial K_{1p}^{5}} \\ \vdots \\ \dfrac{\partial J_p^{T}}{\partial K_{rp}^{5}} \end{bmatrix} \tag{D-28}$$

where K_j^1 is the j^{th} row of the fixed-gain matrix, K_{ij}^5 is the j^{th} row of the variable-gain matrix for flight condition i, J is the total cost, and J_i is the cost for flight condition i.

The vector $(\partial J/\partial K)$ has $n_f + n_v \cdot p$ elements, where n_f is the number of fixed gains, n_v is the number of variable gains, and p is the number of flight conditions.

The transformation of the gradient for the fixed-plus-variable-gain design is then the inverse of the matrix in Figure D-3. That is

$$\frac{\partial J_T}{\partial K} = \Phi^{-1} \frac{\partial J}{\partial K} \tag{D-29}$$

where

$$\phi_{ijk\ell m} = \alpha_i d_{ji}^T Q_i d_{ki} M_i^{\ell j} X_i M_i^{mk^T} \tag{D-30}$$

In Equation (D-30), α_i is the flight condition weight, d_{ji} is column j of D_i, Q_i is the quadratic weighting matrix for flight condition i, and $M_i^{\ell j}$ is the measurement matrix for control j and flight condition i for the fixed gains if $\ell = 1$, or for the variable gains if $\ell = 5$. X_i is the covariance matrix for flight condition i.

Figure D-4 summarizes the incremental gradient scheme using the transformed gradient.

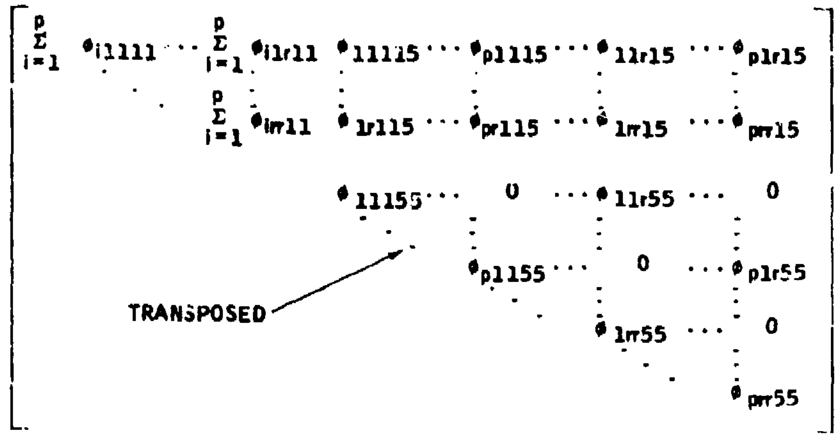

Figure D-3. Transformation Matrix Φ

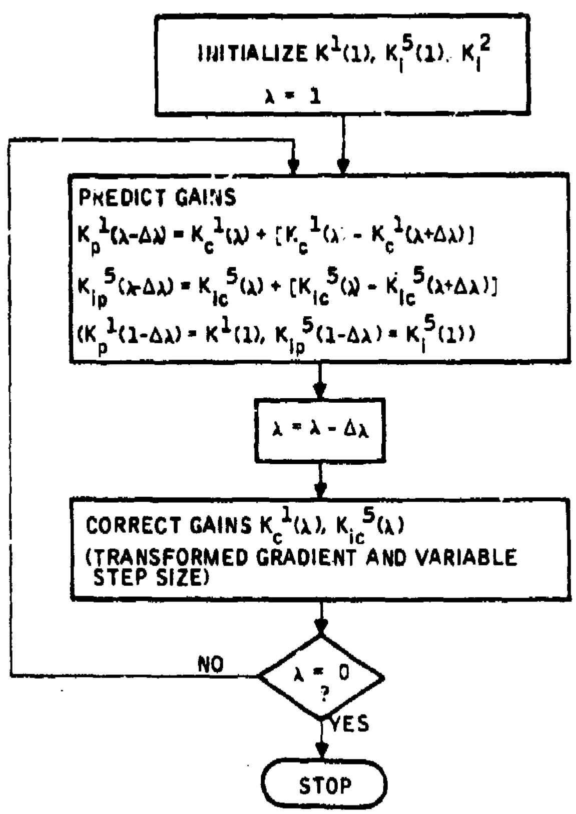

Figure D-4. Incremental Gradient Flow Diagram

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